Competitiveness Effects of Environmental Tax Reforms

COMETR

Final Report
to the European Commission, DG Research
and DG Taxation and Customs Union

NERI, University of Aarhus (Denmark)
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Data sheet

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Abstract: COMETR provides an ex-post assessment of experiences and competitiveness impacts of using carbon-energy taxes as an instrument of an Environmental Tax Reform (ETR), which shifts the tax burden and helps reduce the carbon emissions that cause global warming. COMETR: reviews the experience in ETR in seven EU Member States (Denmark, Germany, Netherlands, Finland, Slovenia, Sweden and UK); analyses world market conditions for a set of energy-intensive sectors, as a framework for considering competitiveness effects; analyses the effects of ETR on sector-specific energy usage and carbon emissions in Member States with carbon-energy taxes introduced on industry; presents a macroeconomic analysis of the competitiveness effects of ETR for individual Member States as well as for the EU as a whole; provides ex-post figures for environmental decoupling and assesses carbon leakage; reviews mitigation and compensation mechanisms for energy-intensive industries.

Keywords: competitiveness; tax; CO_2; socio-economic; macro-economic; energy-intensive; trade; Porter hypothesis; environmental tax reform; double dividend; energy taxation; climate

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The summary report and the annex to the final report are available at *http://www.dmu.dk/COMETR*

Preface

COMETR is a specific targeted research project under the EU's sixth framework programme for research and its activity area 'Scientific support to policies'. In addition to this final report there are two other publications from the project; the annexes and the summary report. The reports as well as further information about the COMETR project can be found on the project web-page http://www.dmu.dk/COMETR.

The results of the final report were presented at the European Commission's TAX FORUM and a subsequent COMETR workshop for specialists, both of which took place in Brussels 19-21 March 2007.

We would like to express our gratitude to all the involved project partners for fruitful and pleasant cooperation. We are also indebted to Ian Perry, DG Research, for helpful advice and counselling on the administrative issues throughout the project, as well as to Katri Kosonen, DG TAXUD, for constructive comments and suggestions for our research activities.

While the financial support from the European Union is gratefully acknowledged, we appreciate as well the academic freedom to pursue the research according to our own plans and reflections. The contents of this report, as well as any omissions or errors, therefore remain the responsibility of the authors and not of the European Commission.

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An introduction to environmental tax reform and the competitiveness issue

WP1

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1 Introduction

The conceptual thinking on environmental tax reform (ETR) dates back to the late 1980's and emerged in a number of European countries at about the same time in response to the growing recognition of the seriousness of environmental problems. The idea to shift taxation from goods to bads – from labour to pollution - was as compelling as it was simple, and starting with Sweden's tax reform in 1989 a number of European countries began cautiously to alter their tax systems in this direction. Yet, from the very start of the ETR-debate concerns about competitiveness impacts on energy-intensive producers have been at the heart of policy-making. In a Europe where trade barriers were removed in the pursuit of a single market, unilateralism in ETR was not a simple undertaking, and the result of introducing tax shifts while at the same time minimising competitiveness impacts has led to complex tax schemes with many exemptions.

Concerns about competitiveness impacts have surfaced in virtually all member states where ETR's have been either unilaterally implemented or under consideration. In view of some draconian proposals to double or triple energy prices the concern has a strong intuitive appeal and is hardly surprising, although in reality most ETR's have adopted cautious and incremental approaches to increase environment taxes, while lowering social contributions or labour taxes.

In many cases the arguments presented on competitiveness grounds refer merely to the budget-economic implications of ETR for individual firms and on the premises on static efficiency. In order for policy-makers to assess such concerns appropriately more rigorous analytical approaches, which bring out the competitiveness effects also at the socio-economic level, need to be applied. There can be little doubt that an ETR will produce some structural effects, with some companies winning and other losing, but rather than the short term impact on individual companies, it is the overall impact on a country's competitiveness which should be of concern to the policy-maker.

The European Commission in its annual competitiveness report defines competitiveness to mean "a sustained rise in the standards of living of a nation and as low a level of involuntary unemployment as possible" (EC, 2004: 17). The OECD less succinctly defines competitiveness as the degree to which a country can, under free and fair market conditions, produce goods and services which meet the test of international markets, while simultaneously maintaining and expanding the real incomes of its people over the longer term (OECD, 1992: 237)

These definitions direct attention to the socio-economic level, and to the need for a country to sustain its ability to produce goods and services which are competitive. The questions which COMETR adress are to which extent well designed ETR's can contribute to such a development, and in perhaps in particular how ETR revenue recycling and mitigation mechanisms can be designed properly so as to minimise adverse effects on competitiveness.

2 The Porter hypothesis on the relationship between environmental regulation and competitiveness

As the first ideas on ETR had gained momentum in the 1980's they were soon associated with the so-called Porter hypothesis. Harvard economist Michael Porter argued in *The Competitive Advantage of Nations* (1990) that contrary to conventional wisdom, environmental standard-setting would actually be able to encourage innovation and hence improve competitiveness, in particular when regulatory standards anticipate requirements that will spread internationally (Porter, 1998: 187). The hypothesis, which reflected and extended a broader literature on regulation and innovation, was put forward within a broader theoretical framework on competitiveness (Ashford et. al., 1985), where Porter argued that clusters of industries facing a 'diamond' of advantageous national circumstances would respond to pressures from outside by seeking more sophisticated sources of competitive advantage and "ruthlessly" pursue further improvements (van der Linde, 1993). Of the four corners in the diamond, environmental regulations would affect particularly the demand conditions for industries, by creating a market for new and greener products, although it would also alter the framework for industry rivalry.

Competitiveness, according to Porter, depends on the capacity of a nation's industry to innovate and upgrade, and it is pressures and challenges, in particular from strong domestic rivals, that lead companies to gain advantage against the world's best competitors.

From his few remarks on the role of environmental regulations for competitiveness in the book two subsequent articles were developed. Most often the joint article with van der Linde (1995) is quoted in the ETR literature, but in a previous essay on *America's green strategy* (1991) Porter is in fact more elaborate on the type of environmental regulations required for beneficial impacts on competitiveness. He points out that most previous environmental regulations have violated the principles for a positive impact on competitiveness, by having emphasised the application of specific pre-defined technologies, often end-of-pipe, rather than leaving room for adaptation, flexibility and innovation. Instead of conventional command-and-control policies, standards should be enforced by market incentives, which also will help contain control costs. It is this emphasis on the use of market-based instruments in environmental regulation, which provides the direct link to the rationale of ETR.

Porter and van der Linde point to six purposes which a well designed, market-based environmental regulation can serve;
- it directs attention to resource inefficiencies,
- it raises corporate awareness and information gathering,
- it provides more certainty to green innovators,
- it can overcome organizational inertia and foster creative thinking,
- it can improve learning, so that short-term losses can be reverted to long-term gains,
- finally, regulation is necessary to induce change, as offsets in many cases are incomplete untill innovation-based solutions have been developed,

The Porter hypothesis generally states that on the longer term there will be innovation offsets from environmental regulations, which will outweigh the costs imposed. Such innovation offsets can be both process and product oriented - the latter are regarded as the most promising in terms of radical shifts which improve competitiveness.

There was vivid controversy in the 1990's over Porter and van der Linde's claims, that low-hanging 10 pound notes had not been picked up by businesses. Palmer, Oates and Portney (1995) took strong issue with the view held by Porter and associates, in their opinion based too extensively on case-studies and anecdotal evidence, rather than on theoretical rigour. While the critics did not deny the existence of innovation offsets, they found them to be several orders of magnitude lower than the imposed costs of environmental regulation. The critics preferred to subject regulations to conventional cost-benefit analysis, where innovation offsets would constitute only a portion of the involved social benefits, and more generally they favoured a social contingency approach rather than one related to competitiveness.

Yet in response to the neoclassical critics many supporters of the Porter hypothesis pointed to the circumstance that organizational slack in company performance is in fact the object of a large body of research literature, and that in real company management the challenge remains to identify and harvest the low-hanging 10-pound notes (Goodstein, 2003).

The double dividend debate

David Pearce (1991) directed attention to the double dividend feature of pollution taxes in the debate on policies and measures that followed the first report from the International Panel on Climate Change. Since pollution taxes serve to correct market failures, by definition they do not share the distorting properties of many other taxes. A fiscally neutral package could be adopted by exchanging distorting income taxes or corporate taxes by carbon taxes – i.e. revenue recycling.

The Pearce argument acknowledges that environmental regulations normally bring a first dividend of social benefits, but because of their long time horizon, and due to the inter-temporal dimension of many environmental issues, the possible existence and magnitude of a second dividend of more short-term immediate benefits for the present-living, was accorded more attention. With CO_2-taxation under consideration this is certainly the case in the climate change issue. The second dividend would then bring increased social welfare, the principal route of effects causing employment to increase, as labour costs lower while energy and environment costs increase.

The "double dividend" hypothesis can be regarded as a slightly more timid version of the Porter hypothesis – it claims that social welfare, rather than competitiveness, is improved when an ETR is applied. However, in the context of the European Commission's white-paper from 1993 the double dividend argument was linked also to the improvement of competitiveness, as the paper advocated to tax "bads" (pollution) rather than goods (labour), so as to improve overall efficiency.

Many economists had difficulties with the 'free lunch' implied in the double dividend argument and with the rhetoric on the win-win options of environmental policy applied by its adherents. Goulder (1994) proposed to differentiate between weak and strong versions of the double dividend argument.

According to Goulder's strong version of the double dividend argument, an environmental tax which replaces another distortionary tax will improve social welfare in any case – which is along the lines of Pearce (1991). The weak version, on the other hand, merely focuses on the revenue-recycling aspect and states that using revenues from environmental taxes to reduce other distortionary taxes is better than a lump-sum return of revenues, which is uncontroversial. Finally, an intermediate form of the double dividend argument states that whether overall social welfare will be improved as a result of ETR depends on the specific properties of the distortionary tax which is replaced with an environmental tax.

The intermediate version of the double dividend argument has been further developed by Bovenberg and de Mooij (1994), who from a public finance position point to the existence of a *tax interac-*

tion effect that countervails the revenue-recycling effect of ETR. In essence the tax interaction effect exceeds the revenue recycling effect except under special circumstances of highly distortionary taxes. The mechanism of the tax interaction effect is that the environment taxes cause commodity prices to increase, lowering the real value of after-tax income. It is claimed that because of labour supply elasticities usually the net effect of the ETR will be negative, as the reliefs on income taxation provided by ETR are too small to offset the price increases.

This finding hinges on the crucial assumption that income taxation a priori minimises the excess tax burden (Weinbrenner, 1996). It also hinges on the assumption, that ETR is introduced on top of existing environmental taxes or regulations that already internalise all externalities.

One important modification to the tax interaction effect occurs if the ETR involves a direct lowering of employers' social contributions, so that no or only marginal price changes will result (Parry, 1994). The swap between environment taxes and social security contributions is one that has been practised in several ETRs.

However, there is much to suggest that many of the analyses which focus on the tax interaction effect are too stylised and restrictive. Bovenberg and de Mooij's first article was based on a static model, in a second article (1997) where they explore the relationships in the context of a dynamic model the findings are relaxed somewhat. If the ETR leads to a lower regulatory pressure on companies then a double dividend may arise.

Nielsen et. al. (1995) explore the double dividend hypothesis with a dynamic model that includes unemployment. They show that unemployment will be reduced if a pollution tax is introduced. In this case the tax interaction effect also influences the value of the unemployment benefit, causing more unemployed to enter the labour market. The overall effect on the economic growth-rate could become negative, however.

Goodstein (2003) generally questions the basic assumption of the tax interaction effect, that higher prices will reduce labour supply. Quoting older empirical literature based on micro-data the relationship is found to be ambiguous. Higher prices in fact lead to an *increase* of labour supply if one considers dual earner families. Workers may increase labour supply partly because they overestimate the reduction in family income generated by the price increases (cf. Gustafson and Hadley, 1989, quoted in Goodstein).

2.1 What kind of efficiency are we talking about?

The problem with much of the debate on the double dividend hypothesis is that it implicitly frames the issue to one of simple *allocative* efficiency. The proposal in the Delors whitepaper (1993) to shift taxation from labour to pollution and natural resources, indeed, was conceived within a conceptual framework of improved allocative efficiency resulting from a change in input factors. However, a number of authors argue that what Porter and others seem to be addressing should probably be regarded rather as *incentive* efficiency (Pearce, 2001).

In a landmark article Berkeley economist Leibenstein (1966) proposes to distinguish so-called X-efficiency from traditional allocative efficiency. While allocative efficiency addresses the optimal combination of productive resources, X-efficiency addresses the optimal use of the individual factor of production. Leibenstein discusses whether labour is always used optimally, citing extensive evidence for productivity improvements achieved in the use of labour. The scope for such improvements would normally be assumed away by neoclassical theory's assumption of optimality and rationality in the management of firms. Yet, in the issue of monopoly regulation, the welfare improvements from X-efficiency could be justified theoretically and empirically to be of a much larger scale than simple allocative efficiency gains.

Leibenstein provides a number of reasons why managers and employees would prefer not to produce at the outermost bound of optimality, e.g. to avoid the required effort and pain of full efficiency. 'It is one thing to purchase or hire inputs in a given combination, it is something else to get a predetermined output out of them' (Leibenstein, 1966:408). The magnitude of the possible improvements in incentive efficiency is represented by an unknown factor X, the reason why Leibenstein introduced the concept under the label of X-efficiency. However, he suggests that X-efficiency accounts for a great deal of the unexplained residual in economic growth.

Much of the anecdotal evidence on inoptimal energy and resource use in the management of firms cited in support of the Porter hypothesis is similar to the evidence on the use of labour that accumulated in the literature following Leibenstein's hypothesis. There are several good reasons why companies would not be rational and optimal in their use of energy as an input factor, and these reasons go beyond simple transaction costs of gathering the necessary information and undertaking the required technical changes. They relate to the degree of slack in human behaviour and in company operations, and the failure to mobilise all the knowledge which is embedded in an organisation. Energy will be squandered away as long as prices are relatively modest compared with other input factors such as labour and capital, but once outside pressure is introduced the companies will be motivated to mobilise the knowledge and technology available so as to control unit costs. Out of such a process the innovations may evolve which may improve economic efficiency and competitiveness.

The literature is abundant on evidence of how energy-efficiency can be improved at little or no cost. In one of the more rigorous explorations DeCanio (1993:445) found that energy-saving projects under the EPA's Green light programme were "far more profitable than any plausible risk-adjusted cost of capital for comparable projects". Most of the case-studies have failed to bring the results further to assessments of the benefits at the macro-economic level. However, in revisiting the study on the impact of waste water taxes on efficiency Andersen (1999; 2005) found that the Netherlands' operate their waste water sector at lower costs than countries not having employed such taxes, and assessed the benefit to 0,2 per cent of annual GDP.

2.2 The traditional indicators of competitiveness

As noted by Fagerberg (1996) competitiveness is an elusive term. While there are many economic concepts completely unfamiliar to the lay person, when it comes to competitiveness everyone appears to know what it means – and to have an opinion about it. If competitiveness was well-defined the research of COMETR could have been more straightforward, but there are various understandings and definitions of the concept at play.

There is disagreement on whether it makes sense to talk about "national competitiveness" in the way that Porter does. Some authors argue that 'competitiveness' applies to firms rather than to countries, cf. the UK's Department of Trade and Commerce (1998)[1] and a much quoted essay by Krugman (1994). Thompson (1998) argues that competitiveness of a country rests on the competitiveness of individual firms, which may not be evenly distributed. One could have a "leopard spot" economy with islands of strongly competitive sectors or firms, and a declining in-between which is not. There is no particular reason to expect that all firms and sectors in a country should be at the same level of competitiveness. In any case most countries have a fairly large domestic

[1] "the ability to produce the right goods and services of the right quality, at the right price, at the right time. It means meeting customer needs more efficiently and more effectively than other firms" (quoted from Budd and Hirmis, 2004)

sector, which is not exposed to competition to the same degree as their export-oriented industries. For this reason most analysis of competitiveness is focused on the manufacturing sector, and leaves aside services and welfare provision.

Despite the ambiguity of the concept of national competitiveness the OECD and several banking institutions have over many years developed relatively sophisticated indicators for national competitiveness (Durand 1987, 1992; Turner and van t'Dack, 1993). Relative exchange rates are crucial in drawing comparisons between changes in competitiveness, but the problem arises that exchange rates fluctuate differently against different currencies, and furthermore, that different competitors are significant on export markets and on the domestic market respectively. When one wants to compare prices or costs between one or more countries one would ideally control for changes in exchange rates in a way that principally adjusts for the relative significance of various markets and competitors in order to draw the right conclusions about changes in competitiveness. As shown by Turner and van t'Dack (1993) the problems of constructing such weighted exchange rates are not small. In the case of the real exchange rate, it requires the use of different indices, weighting systems and specifications of the relations to a country's trade balance, leading to rather different results depending on the specific approaches chosen. One possibility is to take the ratio of one measure to another to paint a wider picture of a country's competitive position, e.g. price to cost indices as a proxy for profitability. In fact, comparisons between results of different weighting methods show that close correspondence exists if the method of double weights is applied (ibid. p. 27).

Manufacturing unit labour costs, which reflect salary levels relative to productivity, seems to be the preferred deflator for real exchange rate changes in competitiveness, although often accompanied by other deflators such as export unit costs and consumer prices (Marsh and Tokarick, 1996). However, the principal disadvantage of using export unit costs is that some companies to avoid loss of competitiveness may decide to export products at less profitable or even unprofitable prices. It also ignores the competition against imports on the domestic market. The principal disadvantage of using consumer prices is that some goods are under price controls, and may introduce noise in the calculations. In addition, a significant part of trade is in intermediate goods, and these are not included in consumer price indices. Unit labour costs are based on data that is widely available and on a comparative basis – the main disadvantage being sensitivity to cyclical movements in productivity over the business cycle. It can be netted out using trend productivity measures.

A more radical solution is to calculate absolute levels of competitiveness. Detailed measures of productivity and estimates of purchasing power parities have allowed for a development of level-based measures. This approach is applied in a recent European Commission Competitiveness Report 2004 (EC, 2994) in a sectoral study of the automotive industry. The principal disadvantage of using PPPs is that it is a measure based on domestic expenditures, not output, but if GDP is corrected for indirect taxes and imports this needs not be a major issue. However, as the study of the automotive sector shows, there can be differences in the absolute level of unit labour costs such as the degree of outsourcing or the amount of intermediate goods supplied, which causes difficulties for the comparison. Although such measures are taken to improve competitiveness, the direct comparison of unit labour costs is somewhat distorted. Especially if the focus is on one or more sectors, rather than the manufacturing industry as a whole, such factors tend to amplify differences in an unfortunate way.

In the context of the Porter hypothesis we should also note that the unit labour cost indicator refers to price competitiveness only and does not reflect the broader preoccupation with incentives for innovation and technological development, which may strengthen competitiveness in the longer run, as implied in the ETR debate.

Indeed the short-run indicator of unit labour costs requires some caution in interpretation, cf. the so-called Kaldor paradox. While increasing unit labour costs normally would be interpreted to imply a loss of competitiveness, they may in fact reflect the ability and competitive strength of a country to market its products as a price-setter, so as to allow for higher labour earnings. Conversely, declining unit labour costs leading to low domestic wages may not fulfil the requirements of the OECD definition above, that "maintaining and expanding the real incomes of its people over the longer term" (OECD, 1992:237) is the litmus test on competitiveness.

Perhaps for this reason in previous analysis of the impact of ETR on competitiveness, the analysis goes beyond the traditional indicators and projects resulting trends in export market shares (cf. Barker, 1998). Still, because of the difficulties with the measurement of changes in market shares ex-post, the quantitative indicators of real exchange rate value and trend productivity growth as measures for short- and long-term competitiveness respectively are, according to some authors, in the end often regarded as more appropriate (Wagner, 2003:15).

The context of ETR raises a further difficulty with the use of unit labour costs as indicator for competitiveness, in that ETR induces differences in energy costs which normally are assumed away. Durand et. al. (1987) note that raw materials such as energy products are traded at world prices, and are not influencing the relative competitiveness, so that they can be assumed away in the comparative analysis. Still, if ETR lowers unit labour costs via increases in energy costs it seems appropriate also to calculate and consider trends in unit energy costs, as these are altered by ETR. If ETR helps companies focus more attention on improving energy efficiency one would expect energy unit costs to decline after the initial price-chock.

2.3 The need to account for technology and innovation

Productivity growth, reliability, delivery times, quality, after-sales service, financing arrangements, technological innovation, investment in physical and human capital as well as the institutional and structural environment are all factors that need to be taken into account in assessing the competitiveness of a particular country (Agenor, 1997:103). But because most of these factors are qualitative, researchers have often abstained from trying to take them into account and have relied mainly on the quantifiable indicators, such as unit labour costs.

However, the paradox is that while the conventional indicators related to price or cost competitiveness would predict losses in market-shares as a result of increases, the experience in the post-war period, as demonstrated by Fagerberg (1988) and Amendola (1988) is that the countries which have experienced the fastest growth-rates in terms of exports and aggregate output, also have had much higher growth in unit labour costs than other countries.

This 'perverse' relationship (Agenor, 1997) between growth in unit labour costs and growth in export market shares can be explained by accounting for the role of relative technological capabilities. Fagerberg (1988) shows on basis of econometric analysis of 15 OECD-countries that unit labour costs play a more modest role than commonly believed. The Kaldor paradox persists in that increasing unit labour costs and increasing market shares tend to go hand in hand. Instead it appears that increases in R&D and in productivity correlate better with increases in market shares for exports. Results of other more sector-specific studies suggest that the link between technological activity and export performance are particularly strong in chemicals and machinery industries, but also exist in less high-tech industries such as metals products and food&drinks (Fagerberg, 1996). Nevertheless, price competitiveness persists in many low-tech industries, as well as in some high-tech too. So as attempted by Agenor (1997) the question is how to account both for the impact of price and non-price factors.

This raises the important question of how the non-price factors can be identified and measured. One approach, applied by Fagerberg, is to take gross investments in physical capital as a proxy for productive capacity. Another more common approach is to measure both R&D activity and patents. The European Commission in its Competitiveness 2004 report devotes a full chapter to the discussion of R&D impacts and in its study of the automotive industry presents data on the composition of R&D expenditure from the Community Innovation Survey carried out by Eurostat. The survey allows for a breakdown of innovation expenditure on various categories and according to NACE classifications (EC, 2004:202).

2.4 Implications for industry sector analysis

As regards the price aspects of competitiveness the ETR philosophy suggests a tax shift from labour to pollution, so that an impact on unit labour costs is to be expected. However, the precise nature of this impact will be likely to vary with the revenue-recycling mechanisms – if social contributions are reduced, the offsets from energy taxes on unit labour costs can be instantly recorded, whereas if income taxes are lowered, unit labour costs will be reduced only when and if the pressure for salary increases slows. This implies that where income taxes have been lowered as a result of ETR, it will be appropriate to consider the trend in unit labour costs over time.

PPP-adjusted unit labour costs seem to be an acceptable methodology, avoiding the complexities of designing currency baskets and weights for adjusted real exchange rates. However, whether unit labour costs should be expected to decline in the longer run as a result of ETR is questionable. If ETR strengthens competitiveness, via innovation of processes and products, it seems as if it would allow for higher unit labour costs, at least in the innovative sectors and industries.

In the industry sector analysis also socalled *unit energy costs* as an indicator for competitiveness impacts have been considered. Unit energy costs are defined as total energy expenditure (incl. taxes) per unit of gross value added in market prices, deflated according to the same method as for unit labour costs. So far unit energy costs were not an issue in the competitiveness literature, which assumed no differences in prices of internationally traded raw materials. The Porter hypothesis seems to suggest that unit energy costs, after an ETR-induced price increase, would lower, as innovation-based solutions to improvement of energy efficiency are identified. Not withstanding the complex aspects of the competitiveness issue, unit energy costs may in fact turn out to be the single most reliable indicator for assessing the Porter logic.

2.5 Implications for macro-economic analysis

The E3ME model addresses competitiveness according to a more comprehensive and dynamic multi-sectoral framework. It is able to model the combined effects of increases in carbon-energy taxes and various revenue recycling or mitigation measures, whether these take place via reduction of social contributions or via lowering of income taxes.

The E3ME model does, via changes in import and export ratios, predict market shares for the individual industrial sectors as a result of ETR – and has been employed ex-post to model the changes in market-shares as a result of specific ETR's in the seven COMETR-countries. It is able to capture inter-industry as well as between-country adaptations to the ETR-induced changes in energy prices. The model addresses price competitiveness, but takes account of technological development via the gross fixed capital formation data. The COMETR-7 countries can be regarded as an example of partly uncoordinated multilateral action. There are several other variables in the E3ME-model which address specific aspects of the competitiveness issue, these include traditional macro-economic indicators such as GDP and employment.

One caveat is that exchange rates in E3ME are assumed to be unaffected by the dynamic effects of the ETR-induced induced changes in energy prices. Whereas much of the competitiveness literature suggests that adaptations to such cost increases would take place via changes in exchange rates, the E3ME-model assumes that the industrial sectors are either price-takers or price-setters – in the latter case without overall implications for exchange rates. Whereas this is a fairly robust assumption for countries in the euro-zone, it needs to be kept in mind when interpreting results for a broader range of countries. The ability of individual industrial sectors to act as price-setters in foreign markets is another important assumption of the E3ME-model, but the assumptions are checked carefully against historical data as part of the COMETR project so as to provide a reasoned background for the overall analysis. The effects on unit costs can be compared to those on export prices to see which sectors have their profit margins squeezed by being forced to accept world prices for their products, whilst being unable to avoid increase in their unit costs.

The E3ME data generally holds data at a more aggregated level, than the more detailed analysis which is available for the industry sector analysis. For instance, while E3ME like most other macro-economic models uses average energy prices, the data which is available for the industry sector analysis is based on sector-specific energy prices and taxes, and is hence better able to capture the differentiated approach with selective exemptions for certain industrial sectors practised in several EU member states.

The need to go beyond conventional price competitiveness is acknowledged broadly in the recent international literature on competitiveness, as well as by the European Commission, so that in the context of ETR and the Porter hypothesis, there is a compelling logic requiring the COMETR project to address not only price aspects of competitiveness, but also non-price aspects.

While the approach of both the bottom-up and the top-down analysis in COMETR is to address price competitiveness, the project will also go beyond and analyse the non-price aspects, although on a more qualitative basis. Although R&D indicators offer some evidence for non-price effects, the case studies to be undertaken on the selected sectors and sub-sectors have compiled evidence and findings via literature, stock exchange information and interviews so as to capture indications for ETR-impacts on competitiveness in the broader sense.

2.6 Final remarks

The Lisbon process has addressed competitiveness as a key concern for Europe and European policy-makers. The COMETR project calls attention to the fact that the principles of environmental tax reform were in fact conceived within a conceptual framework emphasising the opportunities for improving competitiveness through more intelligent designs of the policies and measures adopted for environmental policy purposes.

Although the Porter hypothesis, and its more timid successor, the Pearce double dividend argument, met with as much scepticism as enthusiasm, more than a decade of research and macro-economic simulations have provided sufficient evidence to substantiate, that a second dividend can arise, in particular where ETR is introduced in a context of unemployment and distorted tax systems, with non-optimal internalisation of external costs. In the field of climate policy, where the EU officially has warned that a threshold of atmospheric CO_2-concentrations at 450 ppm would be critical, and could be exceeded within the next 20 years, if business-as-usual continues in fuel use, it should not be difficult to accept the necessity of introducing cost-effective policy instruments. As unemployment prevails as a major social and economic problem throughout the European Union, the COMETR project has endeavoured to uncover what experiences have been attained by the "frontrunner" member states in environmental tax reform, so as to provide a more informed basis for judging the options for a more concerted effort in the post-Kyoto phase.

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Overview of Environmental Tax Reforms in EU member states

WP1

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Abstract

Environmental taxes have historically been applied as a choice for meeting particular environmental objectives. However, in many countries they are increasingly being applied within a general strategy of environmental tax reform (ETR) aiming to address multiple interests and objectives simultaneously.

The concept of an environmental tax reform (ETR) is widely accepted as a reform proposal of the national tax system shifting the burden of taxes from conventional taxes, such as the ones levied on labour and capital, to environmentally related activities, such as taxes levied on resource use, in particular energy, or environmental pollution. The underlying rationale of the tax shifting programme is to address multiple policy objectives assuring that the tax burdens are distributed fairer from an environmental and sustainable perspective. The concept behind this approach is that positive welfare gains will be generated through reducing taxes levied on labour or capital and increasing taxes on environmentally related activities hence helping avoid 'welfare-reducing' activities. Furthermore, the imperative behind a tax shifting programme is one of revenue neutrality meaning that the increase in one is balanced by the reduction of the other, guaranteeing that there is no change in the overall tax burden at the national level. The motivation for implementing this policy instrument is to ensure that the tax burden falls more on 'bads' than 'goods' by guaranteeing that the price signals – as a consequence of introducing environmentally related taxes – provide an incentive to consumers and producers to change behaviour. The basis for implementing environmental taxes within an ETR is the generally accepted premise that taxes are a tool for reaching political objectives effectively and in a cost-minimising way. A typical case is an increase in the tax on energy (whose use leads to pollution, e.g. externalities), and a simultaneous reduction in labour taxes, such as income taxes or social security contributions paid by employers and / or employees, aiming to increase employment (see for a more detailed discussion: EEA 2005 forthcoming).

However, experiences show some caveats impeding the more widespread use of environmental taxes in environmental policy. The most often cited caveats are the potential loss of competitiveness of the domestic industry as a consequence of the unilateral introduction of environmental taxes and distributional issues, i.e. environmental taxes are regressive and affecting the poorer part of the society disproportionate.

The main focus of this paper is to study how are the European countries which have implemented an ETR in the past are addressing the issue of the potential loss of competitiveness. The paper looks into the questions whether the countries considered the competitiveness issue when an ETR was designed and which policy and fiscal measures have they launched to overcome the barriers.

The paper discusses the theoretical concept of an ETR. It further investigates the concept of an ETR in practice, i.e. whether some 'signs' of an ETR can be identified by examining how the ratios of labour taxation-to-GDP and of environmental taxes-to-GDP have developed during the last decade. The main part of the paper deals with the different approaches countries adopted in providing special tax treatment to industries mitigating the fear of losing the competitive position of domestic industries. These country analyses highlights the tax provisions granted to industries as well as the recycling mechanism which must be included in the discussion of how are the countries attempting to tackle the competitiveness question.

1 Introduction

Since the early 1990s several European countries, in particular the Nordic states, are making more widespread use of economic instruments in environmental policy. The prevalent economic instrument to be introduced has been environmental taxes and charges. Reasons for this development are manifold and the main reasons are as follows:

- Economic instruments are more and more seen as a compliment to the then prevailing traditionally regulatory, command-and-control measures. Increased environmental awareness in many societies and the simultaneous realisation of the increased pressure on the environment, mainly in the form of environmental pollution demanded a shift in environmental policy and a search of new economic instruments.
- Theoretical discussions demonstrating the prevailing character and superiority of economic instruments as compared to command-and-control regulations (OECD 2001 and 2004). The political reform process was driven by the aim of becoming more effective and efficient; i.e. achieving political objectives more economical for consumers and producers as well as improving the effectiveness of political intervention. The theoretical and academic analysis shows economic instruments, in particular environmental taxes, can guarantee that these objectives can be achieved with least costs. The main advantage of the political intervention applying taxes is the price signal indicating to consumers as well as to producers to change their behaviour. These price signals provoked by taxes are also seen as the basis for the theoretical advantage of them as they reveal the prospect of realising static and dynamic efficiency gains.
- Fiscal reform proposals have been on the political agenda in many European countries aiming to alter the tax systems, in particular, by reducing taxes levied on labour (income taxes as well as social security contributions). During the last two decades of the 20th century high taxes on labour have been perceived as a cause for high unemployment rates and as an obstacle for employing additional people at a situation when economic growth was low and economies were in depression. Revenues from these taxes have been increased during these decades and were seen as to high, especially in the Nordic countries with rather high marginal income tax rates. Revenues generated from taxes levied on the production factor labour have been a major component of the total increase in governmental revenues in the 1980s and 1990s.

An early concept to address these issues has already been presented in the 1980s by Binswanger and colleagues (Binswanger et al. 1983). Their suggestion boiled down to levy a tax on energy consumption and to use the revenues generated from these environmental tax to reduce the taxes and charges levied on the production factor labour and in particular to reduce the social security and / or pension contribution. Such a tax shifting programme, i.e. an increase of environmentally related taxes with simultaneous reduction of distortionary taxes, such as those levied on labour or capital, is now recognised as an ecological tax reform (ETR) also discussed in the literature as an environmental tax or green tax reform[2].

The concept of an ETR has been transferred into practice in the early and mid 1990s by countries such as Sweden, Denmark, Norway, Finland and the Netherlands followed by the UK and Ger-

[2] The term ecological fiscal reform (EFR) can also be found in the literature. We are following in this paper the differentiation between ETR and EFR as discussed in the most recent EEA publication (EEA 2005 forthcoming): EFR is a broader principle as ETR because it focuses not only on a tax shifting programme but also includes policies aiming to reform subsidies.

many in the late 1990s, although the actual conceptualisation of this rather 'simple' looking tax shifting programme differs from one country to another as discussed below in more detail.

The ETR idea became quite prominent on the political stage when it was promoted by the European Commission in the Delor's White Paper on Growth, Competitiveness and Employment: *If the double challenge of unemployment and pollution is to be addressed, a swap can be envisaged between reducing labour costs through increased pollution charges* (EC 1993).

One of the regularly mentioned features of the ETR concept is the principle of revenue neutrality. The rationale behind this reform process is the strategy of keeping the governmental budgetary position unchanged so that the overall tax burden of the economy remains. However, this does not apply for all sectors of the economy since some sectors will face higher a higher tax burden while the others will face a lower one, i.e. an ETR will lead to both 'winners' and 'losers'. The theoretical discussion on ETR takes the principle serious although the reality looks rather different and demonstrates that revenue neutrality is an option in the context of ETR. An ETR can be – and was – part of a much larger fiscal reform process where the clear political intention was to reduce the overall tax burden of the economy (for example Sweden 1991). Additional revenues generated either via the introduction of new environmental taxes or by increasing already existing tax rates can therefore be used to compensate the overall loss of revenues and mitigated the overall budgetary position. It is therefore worthwhile to state that revenues of environmental taxes – in particular in the context of an ETR – are hypothecated in the sense that the generated revenues are being used to offset – either fully or at least partly - the reduction in the national budgets as a consequence of the revenues shortfall as other taxes or charges are being reduced. In addition, revenues of environmental taxes may also being used to increase the tax free allowances (see for example the situation in the Netherlands regarding personal income tax regulations) or to provide investment subsidies for renewable energy sources (for example, Denmark and Germany).

The use of environmental taxes as an instrument to improve the environmental situation can be traced back to Pigou (1932) who developed the rationale for environmental taxation. Furthermore, environmental taxes are an appropriate tool for implementing the polluters pay principle (PPP) which, in addition to the precautionary principle, is a foundation of European environmental polices (Article 174 of the Treaty of the European Community; i.e. Treaty of Nice). The rationale behind the PPP is to internalise environmental costs (i.e. the costs of environmental damage, external costs) which accruing through environmental pollution.

There is no doubt that environmental pollution leads to a range of damages which are not reflected in market prices. These damages, also described as externalities or external costs, are therefore not being paid for by the polluter but by the society as a whole. The commonly accepted framework of internalising such external costs is the use of environmental taxes (see EEA 2005 (forthcoming). The Pigouvian tax achieves this goal if the tax rate is equal to the marginal social costs and the marginal benefit from emitting an additional unit of pollution (OECD 2001). One of the fundamentals of the Pigouvian tax is that all polluters are facing the same tax rate, i.e. not having any tax differentiation between different economic actors. This finding is also supported by the second approach offered by the economic literature of internalising external costs which goes back to Baumol and Oates (1971). The Baumol and Oates approach differs from the Pigouvian tax insofar as the tax rate is set on a level estimated to be sufficient to reach a given and predetermined political environmental objective. However, both approaches concur that in a first-best situation the tax rate is uniform for all polluters guaranteeing that the objective is achieved at least costs.

The current political practice looks rather different because many energy taxes – introduced regularly as part of ETRs in different European countries – are discriminating between energy users[3]. The reality shows that special tax provisions, such as complete tax exemptions or reduced tax rates for energy products or tax rebates, for the industry as a whole or only for some industrial sectors, which are generally defined as energy-intensive sectors, are the rule and not the exception. The preferential treatment of these industries, in particular energy-intensive industries, with regard to lower energy tax rates is frequently founded and justified through the risk of the potential loss of competitiveness[4] when these taxes are introduced unilaterally.

In addition, the current energy tax policy in European countries does not follow the theoretical rationale as laid down by Pigou either because tax rates are generally set lower than marginal social damage costs for energy products with the exception of taxes levied on transport fuels. Reasons that the Pigouvian approach has not been adopted in Europe are manifold. The monetary estimation of environmental damages is a rather complex task and linked to great difficulties in assessing these external costs (see for example EC 2003). In addition, it is politically not feasible to set 'optimal' tax rates because governments are facing stiff resistance from industries using competitiveness arguments to block almost any increase in energy tax rates. The situation is rather different when analysing energy taxes on transport fuels as these taxes currently in place in EU member states are by far the highest in the world. This is certainly not surprising because the primary motivation for transport fuel taxes is to generate revenues as these energy taxes have been introduced as early as 1930s as a typical instrument for generating revenues and environmental considerations used for the justification for implementing energy taxes became only more widespread in the 1980s (EEA 2000).

Another theoretical argument often used to support the concept of the special tax provision to industries is that high uniform tax rates would result in a reduction of environmental pollution in the countries levying the tax while it could be expected that the environmental pollution would increase on the global scale correspondingly. This development would be the consequence of the relocation of industries from the heavily taxing countries to those where the environmental tax burden is lower[5]. Relocation of industrial production owing to stricter environmental regulation has been discussed in the economic literature in some length and is well known as the Porter hypothesis (see for example Porter and van der Linde 1995). A proof of this argument could not be found in reality. Interesting to note is also the fact that the political debate linking the issue of competitiveness with the implementation of environmental policy instruments also started in the light of the recent introduction of emission trading in the EU (Ekins and Barker 2001, Kuik and Mulder 2004). A major difference between the recently introduced EU Emission Trading Scheme (Directive 2003/87/EC) and environmental taxes is apparent as the former is much closer to the 'raw model developed in economic text books' as it is the case in the latter which are regular far from the theoretical concepts (see for a detailed discussion of the theoretical foundation of emission trading and its transformation into political reality: Chapter 2 of EEA 2005 (forthcoming)).

The theoretical analysis of granting special tax provisions to industries exemplifies the risk that tax provisions can impair the realisation of efficiency gains. But one of the reasons and motivation for introducing environmental taxes as compared to traditional regulatory measures is exactly the efficiency argument (OECD 2001). Furthermore, tax provisions can impede the utilisation of the

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[3] This is normally not the case for transport fuels with the exception of taxes levied on diesel fuels used by haulage companies which are eligible for some form of tax rebate in some EU member states.

[4] The intention of this paper is to provide an overview of the current status/situation of ETRs implemented in some EU member states focusing largely on how the industry as a whole or individual industrial sectors in the EU member states are affected by energy taxation. A detailed discussion of the term competitiveness is done in DL 1.1 (Anderson 2005).

[5] This development is referred to carbon leakage in the literature – *will be dealt with in a further work package of COMETR.- work package 5*

potential of cheap emission abatement efforts in the production sector and must be offset by more costly emission abatement option in the household sector to reach some predetermined emission reduction target as it is in the case for CO_2 emissions (Kohlhaas 2003). This can lead to 'substantial excess costs' as it is stressed in the economic literature (Böhringer 2002).

2 Rationale / objective of ETR – the theory behind the ETR concept

The concept of the 'double dividend' hypothesis (Pearce 1991 and Repetto et al. 1992) is closely associated with discussions on ETR. The case behind this concept is that ETR can trigger off both improvements in environment (eg. an environmental benefit) and in the economy, in particular by increasing employment given the reduction in the tax burden levied on labour (eg. an economic/employment benefit – see for example Goulder 1995, Ekins 1997).

The discussion about the introduction of an ETR has revolved around the concept of the 'double dividend' hypothesis for several years, especially in the economic literature. Proponents of the hypothesis are arguing that both environmental and employment benefits can be achieved simultaneously in the form of a decrease of pollution externalities and by lowering unemployment via the reduction of labour costs. The rationale behind this approach is that the existing tax system entails severe distortions in the economy and these distortions can be eased by using the revenues generated from environmental taxes to reduce the rates of some of these distortive taxes. However, opponents of this concept are arguing that this discussion is too simplistic ignoring some of the links between the newly introduced environmental policy measures and the existing tax system which can be the source of enlarged deadweight losses, in particular arising from the labour market (Parry and Oates 2000). The labour market is distinctively distorted because of the considerable wedge between the gross wage to be paid by companies and the net wage received by employees. The theoretical discussion questioning the existence of a double dividend is based on three different effects on economic welfare. Parry and Oates distinguish between the 'primary welfare gain', the 'revenue-recycling effect' and the 'tax-interaction effect' (Parry and Oates 2000, p.606).

The first effect is rather straightforward because it shows to the benefits arising from the environmental improvement. The second effect originates from the fact that the revenues generated by environmental taxes can be used to reduce the rates on existing distorting taxes, such as the ones levied on labour, i.e. income taxes or social security contributions. The revenue recycling effect is therefore a source of welfare gain and it cuts the wedge between the gross and net wage leading to an increase in employment.

The third and last effect is of particular significance in theoretical discussions assessing the overall effect of an ETR because it illustrates how the environmental tax interrelates with the existing labour tax system. A large number of analytical simulation studies as well as theoretical modelling approaches are reporting that the tax-interaction effect is causing a welfare loss because real household income is shrinking as a consequence of the introduction of environmental taxes. The reduction in real household income triggers out a reduction in labour supply and this effect could outweigh the revenue-recycling effect meaning that an overall increase in employment will not materialise. However, these findings are crucially depending on the framework conditions (see for a detailed discussion: Parry and Oates 2000, Ekins and Barker 2001 and Parry 2003). As a consequence of the fact that the theoretical discussions on the double-dividend hypothesis is still ongoing, the position prevails nowadays arguing that the double dividend hypothesis should not necessarily be used as a justification for launching an environmental tax reforms. The improvement in environmental quality should be singled out as the major political objective and this fact should then be discussed in the context that the overall tax burden will remain at least constant (i.e. no net tax increase). In the case that an additional benefit will occur, such as an increase in employment then this development should be seen as a welcome and added positive outcome.

This latter point has particularly should be more elaborated in the political discussions because the environmental tax corrects a 'distortion from a pre-existing environmental externality' (Ekins and Barker 2001, p.333). It must therefore be kept in mind that the introduction of the concept of an ETR addresses pre-existing tax distortions, especially at the labour market. There is no doubt that the labour market is badly distorted as labour taxation, being either in form of income or payroll taxes or in form of social security contributions, is driving a wedge between the gross wages paid by employers and the net wage received by employees. Furthermore, the theoretical discussions are often factoring out one of the main criteria and properties of environmental taxes that namely such economic instruments are stimulating the development and adoption of new – less polluting – production technologies. This feature is often neglected although one of the key advantages of economic instruments - as compared to regulatory command-and-control approaches - is the potential to achieve dynamic efficiency gains, i.e. to provide an ongoing incentive to reduce pollution abatement costs via the implementation of less polluting and therefore environmental friendlier technologies (OECD 2001). However, this specific feature of environmental taxes can only make an impact in the medium to long-run as time goes by before new technologies triggered out by the introduction of new or by increase of existing environmental taxes are implemented and show their full potential in reducing environmental pollution.

Parry and Oates (2000) emphasise that many of these simulation studies and analytical modelling approaches are resorting to assumptions, such as that the labour market is competitive, which do certainly not hold in the European context where many more regulations do exist as it is the case in the US. Their conclusion is therefore somehow interesting, in particular when assessing ETR approaches actually implemented in different countries: '*Perhaps the revenue-recycling effects that result in lower taxes on labor and the tax-interaction effects from a reduced real wage operate a bit differently in the context of some of these institutional features of European labor markets* (Parry and Oates 2000, p.611).

Probably the leading theoretical discussions associated with the application of environmental taxes and regarding the introduction of an ETR are connected with the Porter hypothesis on the one hand and the double dividend hypothesis on the other hand. Although the two hypotheses are addressing somewhat slightly different features of environmental policy, they are significant when analysing competitiveness. The link to the question of competitiveness is rather straightforward in the case of the former as it looks into the effects of stricter environmental regulation on the performance of industries, i.e. whether the competitive conditions are impeded through environmental policy measures, including environmental taxes. Stricter environmental regulations are frequently reflected in higher cost for the industries affected at least in the short run. Industries may also be affected with higher costs when an ETR has been implemented. These higher costs may be offset – either partly or fully - through the reduction of other taxes and charges although it is not guaranteed that all industries are compensated, i.e. industries in some sectors may face higher net total cost as the compensation via the reduction of taxes does not countervail the increase in environmental taxes. Therefore, it can be summarised that the two hypotheses are of relevance when analysing the issue of competitiveness as both underlying policy approaches are affecting the cost structure of industries – positively in the short run.

3 Current situation – overview of ETR in Europe

3.1 EU 15

Significant tax reforms have been undertaken in European countries during the 1990s and their main objectives have been to reduce labour costs, to broaden the overall tax base leading to an increase in general consumption taxes, such as VAT and environmental taxes. During this period and as part of such substantial tax and fiscal reform efforts the Nordic governments adopted the concept of an ETR followed by the governments of the Netherlands, the UK, and Germany. The strategy taken by those countries was to launch new environmental taxes, in the majority of the case taxes levied on the consumption of energy and CO_2 emissions, and to revise already existing ones. The other component of the tax shifting programmes was mainly done by reducing income taxes as well as non-wage costs, such as social security contributions, and by raising the tax free allowances with regard to incomes. An overview of the main tax shifting programmes implemented in EU member states can be found in Annex 2 (for further discussions on ETR see: Hoerner and Bosquet 2001 and EEA 2005 (forthcoming)). Some of the tax reform packages also included components directly addressing the business sector by providing support schemes for investment into energy efficiency. Tax reform proposals to reduce the capital tax burden of industries became high on the political agenda only recently, in particular, as a consequence of the low capital taxes levied in some of the new EU member states.

Revenues generated from environmental taxes expressed as the share to total taxes generated or GDP is regularly used as an indicator for illustrating the significance of environmental policy in a country. The interpretation of such comparisons of tax revenue figures must be treated with some cautious because revenue figures do not say anything about the 'environmental friendliness' of the overall fiscal policy or environmental policy in a certain countries. Nevertheless, such ratios are regularly being used to study whether a country is moving into the direction of an ETR (EEA 2002), i.e. by comparing the development of the labour taxation-to-GDP ratio and the environmental tax-to-GDP ratio.

The labour taxation-to-GDP ratio increased throughout the 1990s in almost all EU 15 member states although the political objective has been to reduce the cost of labour and thereby to increase employment (see Annex 1). During this decade the environmental tax-to-GDP ratio also increased in the majority of EU member states as a consequence of the increased application of environmental taxes. However, the trend of increase in the labour taxation-to-GDP ratio slowed down and changed when studying the situation in the mid 1990s (i.e. 1995) as compared to 2002[6].

The expected result of an ETR – a decrease of the labour taxation-to-GDP ratio and an increase in the environmental tax-to-GDP ratio – occurred in those EU member states which implemented explicitly an ETR: Denmark, Finland, Germany and the Netherlands. In addition, the same development can be found in Austria. Interesting is the result in Sweden because an ETR development is recorded when studying the labour taxation-to-total tax revenue ratio vs the environmental tax-to-total tax revenue ratio but not in the case when the ratios are expressed with regard to GDP. Sweden and in addition the Netherlands and the UK are rather similar because these three countries reduced the total taxation-to-GDP ratio between 1990 and 2002 considerably as compared to

[6] It has to be noted that these results are only indicative because they partly depending on which years are used for the comparative analysis.

Denmark, Finland and Germany where this share remained almost constant. An interesting development can be recorded for Austria because a movement into the direction of an ETR can be found and in addition the total taxation-to-GDP ratio increased during the time period 1990-2002. Another exception is the situation in the UK because the ratio labour taxation-to-GDP remained stable between 1995 and 2002 and the environmental taxes-to-GDP ratio decreased slightly although new environmental taxes have been introduced during this time period. A rather similar development can be reported from the new EU member states. The biggest advance in terms of changes in the labour taxation-to-GDP ratio towards an ETR is found in Estonia and Latvia during the period 1995-2002 (see for a more detailed discussion concerning the situation of ETR in the ten new EU member states: Section 3.2 below).

Before discussing the ETRs implemented in several EU member states in more detail the political development and attitude in France and Italy regarding ETR is discussed. Although both countries adopted ETRs in the late 1990s, the tax shifting programmes have never been taken place because of different reasons.

The Italian reform proposal foresaw a modification of the already existing excise taxes levied on petroleum products in accordance to their carbon content and the introduction of a tax levied on other energy used in combustion plants. The additional generated revenues have been hypothecated for different reasons: (1) for reductions of compulsory labour contributions, in particular for unskilled labour in poorer regions; (2) to finance compensation measures; and (3) to promote energy efficiency measures. The reform package was planned to be introduce over a seven year period (1999 – 2005) accruing additional revenues of 1.1 billion EUR in 1999 raising to 5.4 billion EUR by 2005 (Hoerner and Bosquet 2001). However, this policy has never really kick-started as the Italian Government suspended the tax reform as a response to an increase in world oil prices (OECD 2001).

The French ETR became known as through the concept of 'Taxe Générale sur les Activités Polluantes' (TGAP). The purpose behind this concept was to unify and simplify a whole range of environmental taxes (on industrial and domestic wastes, atmospheric pollution, oil and noise) and to introduce new taxes (on detergents, extracted materials, pesticides in 2000 and energy – planned to be implemented in 2001). The revenues of the TGAP was planned to be used for reduction of payroll taxes and 75 percent of the revenues should have been generated by energy taxes which were planned to be introduced in 2001.

The energy tax rates – initially set between 23 and 30 EUR per ton of carbon in 2001 - should have been gradually increased reaching 76 EUR in 2008-2010. The energy tax was designed as a tax on business as only companies with an energy consumption of more than 100 tons oil equivalent should have been subject to the energy tax. Other sectors, such as agriculture, fishery, forestry as well as road transportation and households were to be exempted. In addition, special tax provisions were planned for industries with the reduction in the tax rates varying with the energy input relative to the value-added for each individual firm as the consequence of active lobbying of energy intensive industries. However, the planned tax rebates were linked to an obligation to negotiate voluntary agreements with the administration. Although the TGAP-energy tax was adopted by the French Parliament it was never implemented as it was found unconstitutional by the Constitutional Council. In particular, the tax failed as it did not respect the principle of equality in taxation. Furthermore, the proposed tax would lead to distortions as it would discriminate among different categories of energy consumers leading to the perverse outcome that lower levels of energy consumption could incur higher levels of tax (Deroubaix and Leveque forthcoming).

3.2 EU-10 - the new EU member states[7]

Although the use of environmental taxes and charges in environmental policy has a long tradition in Central and Eastern European countries (CEECs), an ETR in the sense that an explicitly announced policy shifting the tax burden from conventional taxes, such as labour, to environmentally damaging activities, such as resource use or pollution, comparable to the development in some of the old EU 15 member states has not taken place. However, countries of the region have revised tax policies as well as they have implemented changes in the overall public finance systems during the last years. These changes were often linked to and a consequence of the requirements of the EU accession process. Environmental taxes, in particular those levied on energy products, have been revised during the 1990s (Speck et al. 2001a). Despite the still relatively lower tax rate as, the revenues from environmental taxes and charges reach often similar GDP shares as it is the case in the six old EU member states implemented ETRs (see Table 2 in the Annex 1). Differences can be found between the CEECs as the environmental tax-to-GDP ratio has been almost kept constant in countries, such as the Czech Republic and Hungary, during the period 1995 – 2003 as compared to the situation in the Baltic countries, which more than doubled during the same period but is still below the average of the EU 25 and of the new EU member states. It is also worthwhile to mention that this share is above the average share of the old EU member states (EU 15) in Cyprus and Malta. However, as mentioned above, this ratio can only be used with some cautious as a high share cannot be equated with 'environmental friendliness' of the overall fiscal policy in the country.

A further feature of the environmental tax and charge system in CEECs requires some attention as these countries have a long tradition in earmarking revenues from environmental taxes and charges, in particular from pollution and resource taxes, to special parafiscal environmental funds (Speck et al, 2001b). Environmental funds are still playing a role in co-financing environmental investment infrastructure as part of the transposition of the requirements laid down in the *environmental acquis* as the CEECs are still facing a major backlog in environmental infrastructure investments.

As it is the case in the old EU 15 member states the major share of environmental tax revenues are generated via taxes levied on energy products (between 65 and 80 percent) in the new EU member states with the exception of Cyprus and Malta where around 60 percent of environmental tax revenues must be attributed to transport related taxes. Some increases in energy tax revenues will happen in the new EU member states in the near future as a consequence of the adoption of the 'Taxation of Energy Products Directive' (Directive 2003/96/EC of 27 October 2003). This Directive restructuring the Community framework for the taxation of energy products clearly widens the scope of the pre-existing EU energy taxation framework, which had previously been addressed by the Mineral Oils Directives (Directive 1992/82/EEC) by setting minimum excise tax rates only form mineral oil products. The new framework for the taxation of energy products extends the number of energy products as minimum tax rates are set for all energy products including natural gas, coal and electricity, as well as increasing the minimum rates for transport fuels that had been set by Directive 92/82/EEC. All EU member states including he new EU member states from Central and Eastern Europe are obliged to comply with fiscal structures and the levels of taxation laid down in the 2003 Taxation of Energy Products Directive. However, the new EU member states negotiated temporary exemptions and transitional periods for the full compliance with the regulations as the straight transposition may create serious economic and social difficulties in view of the ongoing economic transition. The transition periods granted to the new EU member states – in

[7] This chapter is based on Máca et al. 2005 discussing the situation in the ten new EU member states in more detail.

some cases up to 2009/2010 - will reduce the revenue generating effect of energy taxes for the near future (see for a more detailed discussion: Máca et al. 2005). In addition, some of the new member states are already imposing tax rates on transport fuels (petrol and diesel) exceeding the EU minimum rates with the consequence that there is no need for further increases (EC 2005). This is insofar important when discussing an ETR as taxes levied on these energy products are generating by far the highest revenue streams.

One of the political reasons for implementing ETRs in the old EU member states is the high tax burden on labour which is seen as a cause for the high unemployment rates in these countries. The principle of taxing 'bads' and reducing the tax burden of 'goods' must be seen in this context as the process of lowering taxes on labour is anticipated to create new employment and thereby reducing unemployment following the double dividend hypothesis.

The analysis of the situation of unemployment in the new EU member states reveals that unemployment rates are often exceeding the EU 15 average, in particular in Poland and Slovakia where the rate is almost twice as high (Máca et al. 2005). Furthermore, the tax burden on labour income as measured by the implicit tax rate on labour[8] is in CEECs, such as the Czech Republic, Hungary and Slovenia, comparable to the situation in the six ETR countries of the EU 15 (see Table 3 in Annex 1). This result is interesting as it shows that new EU member states are facing similar challenges as old EU member states: a high tax burden on labour as well as high unemployment rates. However, labour costs, i.e. the compensation of employees and labour taxation including social security contributions, are only a small share as labour costs in the old EU member states. It can therefore be concluded that this situation of both high unemployment and high labour tax rates in some of the new EU Member States may create conditions assuming that the introduction of an ETR would be a way forward to overcome this condition. In addition, new energy taxes will certainly be introduced over the coming years as these countries have to comply with the regulations and minimum tax rates laid down in the Taxation of Energy Products Directive. This is certainly of some relevance for the four largest new EU member states, i.e. the Czech Republic, Hungary, Poland and Slovakia, and also for the Baltic countries (Estonia, Latvia and Lithuania). The latter three countries have on the one hand low energy tax rates but combined with unemployment rates and implicit tax rate labour slightly exceeding the EU 25 averages. Slovenia, the wealthiest of the CEE country as expressed in GDP per capita, has also a relatively tax burden but the unemployment rate is below EU average. The situation in the last two new EU member states, Cyprus and Malta, is rather different as both countries have introduced a whole range of energy taxes, in particular Cyprus (see EC 2005). The development of the labour market is interesting as the unemployment rates are rather low and in addition the implicit tax rate on labour is by far the lowest in the EU 25.

Based on the rather bleak situation in at least some of the new EU member states it seems that the introduction of an ETR could be a tool for easing some of the pressures. However, the ETR approach has so far not entered mainstream politics as this concept has mainly been supported by environmental NGOs and by a handful of environmental ministries in different countries (Czech Republic, Estonia, Hungary and Poland).

[8] The implicit tax rate on labour is used by statistical offices, such as Eurostat, to measure the average effective tax burden on different types of economic function. The implicit tax rate is calculated as the ratio between the taxes on income including social contributions and the compensation of employees plus the wage bill and payroll taxes (see for further information: Eurostat 2005).

4 Competitiveness and ETR – how have energy taxes developed over time?

The current energy tax policy in European countries does not follow the theoretical rationale because tax rates are generally set lower than marginal social damage costs for energy products except transport fuels as discussed above. In fact European countries adopted quite different strategies to reduce the effective tax burden for industries when either new environmental taxes have been introduced or existing ones increased. These policies have in common that they are aiming to protect domestic industries because of the fear of the risk of competitiveness as a consequence of the unilateral introduction of energy taxes. The logic behind this policy is relatively straightforward, in particular when analysing energy taxes at the firm or sector level. Any type of taxes, including energy taxes, adds to business costs and in cases where such taxes are introduced unilaterally these additional costs can impair the international competitiveness of the business or sector (for a more detailed discussion: Ekins and Speck 1999). However, some other aspects have to be kept in mind when studying the potential impact of energy taxation on international competitiveness.

Exchange rate variations require mentioning since the world market prices of some of the energy products are expressed in US Dollar and during the last four to five years the exchange rate between the EURO and US Dollar were subject to large changes of around 30%. When analysing the potential negative impact on competitiveness not only the energy tax burden but the total energy prices paid by industry must be considered. The end-user price of energy products is composed of different factors, including the import price as well as the energy taxes levied on the individual energy products. Import prices of the same energy product can vary between EU member states (see Annex 3). The almost exclusive consideration of the potential impact of energy taxes when analysing international competitiveness is therefore often too simple and biased. This issue must also to be seen in the context of how final end-user electricity prices are set because of the relatively big differences in the network tarification between European countries (Speck and Mulder 2003) with the consequence that the setting of network tariffs influences the final end-user electricity price quite considerable (see for a more detailed discussion: EC 2002). When discussing special tax provisions given to industry in the context of international competitiveness, the analysis must not be restricted to a pure analysis of the price elements but also non-price elements of competitiveness must be taken into account. The competitive situation of an industry is also determined by non-price elements, such as production methods and regulations (see EC 2004 and Baranzini et al. 2000). Although these aspects definitely deserve a more detailed analysis, the main focus of this report is directed to the analysis of energy taxation and how EU member states implementing measures in terms of special tax provisions with the political aim of tackling the fear of the loss of international competitiveness.

The main approaches of tax provisions granted mainly to industries impeding the potential of risk of losing competitiveness implemented in EU member states can be summarised as below[9]:

- Tax subject - tax provisions with regard to the energy product:
    - Energy products are exempt from energy taxes; examples are coal in Germany, natural gas in Norway. However, this option of tax differentiation will soon be brought to an end as a consequence of the adoption of the EU 'Taxation of Energy

[9] Different terms are being used in the literature for tax differentiation, for example Vehmas (2005) uses the term tax departures instead of tax provisions when discussing special tax regulations.

Products Directive' (Directive 2003/96) in 2003. This directive widens the scope of the EU energy taxation framework because the new framework establishes minimum excise taxes levied on all energy products including natural gas, coal and electricity[10] and increased the existing ones which have been constant since they were first fixed in 1992. It can therefore be said that the increase in excise tax rates is in fact a policy approach of adapting the tax rates so that the real value of them remains constant

- Tax level – tax provisions with regard to setting of tax rates:
    - Granting tax reduction or complete tax exemptions to economic sectors (Sweden, Germany). The adoption of the 2003 Energy Tax Directive brings the complete tax exemption of economic sectors to a standstill. However, the granting of reduced energy tax rates to economic sectors is still permitted under the new directive but only when special regulations are taken into account (see for a more detailed discussion: Chapter 3 EEA forthcoming).
    - Implementing some form of refund systems for economic sectors. Several EU member states including Austria, Germany, Sweden, Finland make use of this option. The energy tax bill of energy-intensive industries cannot exceed a predefined maximum amount. A unique definition of how to define energy-intensive industries does not exist although the EU Energy Products Directive names two different indicators. However, EU member states can also apply more restrictive indicators and all these indicators have in common that they are expressing the term energy intensity as a ratio between the total energy nbill and the economic performance of an industry using the production value or valued added as an indicator.
    - Tax rates are implemented in a degressive way. This option is widely used in the Netherlands: higher consumption of natural gas and electricity are levied with a lower tax rate (see Chapter 4.4 below).
- Tax provisions based on the quantities of energy products to be consumed:
    - Provision of a tax ceiling: Again this scheme was applied in the Netherlands and was abolished because of EU regulations. The basic approach was that all energy consumed exceeding a predetermined level is not subject to energy taxation. This scheme was replaced by a two tier structure: energy consumed below the predetermined level is taxed with the normal rate and energy consumed exceeding the level faces a very low tax rate.
    - Provision of tax-free allowances: This scheme was used in the 1990s in the Netherlands: a basic amount of energy products are not subject to any energy taxation. However, this tax differentiation is not in accordance with EU regulations and ended therefore. The underlying rationale of this policy has been some social considerations. Nowadays Dutch households receive a fixed refund on the energy taxes per connection. This policy option of implementing special tax provisions is rather different from the other policies discussed so far because it clearly targeted the private sector, i.e. households. The introduction of this type of tax provisions is to address distributional issues related to energy taxation.

The analysis of energy taxation and competitiveness does not end with studying only the favourable provision of tax differentiation for industries. The majority of energy taxes introduced since the beginning of the 1990s are part of an ETR meaning that the revenues generated from energy taxes have been recycled back to the economy through different measures. The most prominent

[10] Energy products consumed in the electricity generation process can be fully exempt from any form of energy taxation under the Directive because output taxation is generally applied for taxing electricity instead of input taxation.

and applied method is to reduce taxes and charges levied on labour either in form of reduction of income tax rates or in form of reduction of non-wage costs, such as reduction in social security contributions. In addition, some EU member states provided subsidies for investments into energy efficiency improvements especially targeting energy intensive industries. The former recycling mechanism is of central significance in our analysis because the reduction in labour costs, which are facing industries, must be considered in the analysis of the effects of an ETR on international competitiveness. To disregard this issue – as it is often the case – blurs one of the objectives of an ETR and the often discussed underlying rationale of the reform process of introducing an ETR namely the principle of revenue neutrality although this principleis regularly not being implemented in its strict form and is the choice and not the mean to implement an ETR.

Revenue neutrality is perceived in the academic and theoretical literature as one of the foundations of ETR the reality looks slightly different as discussed in the country studies below. This principle is regularly softened in reality so that the overall tax burden does not remain the same. It can rather been described as if revenue neutrality serves as a purely presentational device in the political reality. This development need not contradict the underlying rationale because ETR can also take place as part of a much larger fiscal reform process as it is the case in Sweden (see Chapter 4.6 below). The revenues generated by environmental taxes are used to compensate the overall reduction in labour taxes. Therefore it is noteworthy to mention that revenue neutrality is only an option within the ETR framework. However, it must also be mentioned that countries, such as Germany, stipulating revenue neutrality as one of the guiding principle for implementing an ETR, have forborne from this policy goal in the meantime because of severe problems with budget deficits.

The following chapters are describing the major ETRs implemented in EU member states and in addition we highlight the development in one of the new EU member states, namely Slovenia. This country is chosen because it was the first of the 10 new EU member states introducing a CO_2 tax aiming to cut down greenhouse gas emissions and to reduce the consumption of non-renewable energy products (REC 1999 and Speck et al. 2001a).

The main focus lies on a detailed discussion on how energy tax rates have developed over time and which special tax provisions have been implemented in order to address the often quoted risk of losing international competitiveness made by industry. Our discussion centres around energy taxes levied on energy products used for industrial/commercial purposes and heating and not on transport fuels. Although this form of energy taxation is the most prominent one, in particular in terms of the revenue generating potential, we do not analyse it in this report. It is out of question that taxes levied on transport fuels are of significance and special tax provisions have been granted and are still partly granted to haulage companies in some EU member states, such as Italy, France and the Netherlands. Nevertheless our focus is directed to examine exclusively energy taxes levied on energy products other than transport fuels. But as mentioned above the recycling mechanisms - as an integrative part of the ETR reform process - must be taken into account in this discussion too.

4.1 Denmark

Denmark was one of the first countries in Europe introducing a CO_2 tax on top of already existing energy taxes levied on oil products, coal and electricity consumption but not on petrol. The CO_2 tax was introduced in two phases; it was levied on energy products consumed by households in

May 1992 and in January 1993 for businesses[11]. Interesting to note is the fact that the introduction of the CO_2 tax was partly offset via the reduction in the existing energy tax rates (see Tables A1 in the Annex 4).

The introduction of the CO_2 tax in 1992 was a turning point in energy taxation especially for industrial energy consumption because energy consumption by industry was exempt form paying the energy tax. During the period 1993 to 1995 industry was granted a 50% reduction of the CO_2 tax rate, i.e. instead of the 100 DKK per ton of CO_2 energy consumption by industries were subjected to a 50 DKK per ton CO_2 rate. A three-tiered reimbursement scheme granting further tax relief was put in place in 1993, which was set up in accordance to the energy intensity of each business. The refund scheme was differentiated based on the actual energy costs paid and in relation to total sales (Malaska et al 1997):

- If the CO_2 tax burden was between 1 and 2 % of the difference between sales and purchases (i.e. net sales), the company was eligible for a tax refund of 50% of that part exceeding the 1% limit.
- If the CO_2 tax burden was between 2 and 3 % of the difference, the tax refund amounted to 75% of the part exceeding the 2% limit.
- If the CO_2 tax burden was above 3 % of the difference, the tax refund was 90% for that part exceeding the 3% limit. Companies falling under the 90% refund scheme could receive additional tax support covering the remaining part of the CO_2 tax burden. However, this support was limited to three years only and the company had to pay at least DKK 10,000 in CO_2 taxes.

This refund scheme was valid until 1995[12] and was adapted when the second phase of the Danish Environmental Tax Reform was introduced in 1996.

The Danish ETR reform process can be distinguished between three phases.

- 1993 Tax Reform/Phase 1: period 1994 – 1998
    - Political objective of the ETR: The over revenue loss through the reduction in income taxes amounted to around 2.3% of GDP in 1998 – a total tax shifting programme of around 45 billion DKK occurred in 1998.
    - Tax shifting programme: Reduction in revenues generated from income taxes were offset by environmental taxes – anticipated increase of revenues of 1.2% of GDP - and payroll taxes – increase of 1% of GDP.
    - The household sector was targeted in Phase I.
    - Additional environmental taxes have been introduced – tax on tap water, wastewater tax, tax on plastic and paper bags. Revenues from energy tax, which were increased, accounted for 7.5 billion DKK of the projected 12 billion DKK coming from environmental taxes.
- The 1995 Tax Reform/Phase 2: period 1996 – 2000
    - Seize of tax shift programme was smaller as compared to the first phase; e.g. it was projected that revenues raised from environmental taxes amounts to 2.45 bill DKK – around 0.2% of GDP in 2000.
    - Tax shifting programme: Reduction in employers' social security contribution and the provision of subsidies for investment in energy efficiency programmes (see Table 4.1 below for detailed information on the recycling mechanisms) were offset by

[11] Industry was also liable to pay CO_2 tax in 1992 but the whole CO_2 tax paid by industry was refunded in 1992 (Nordic Council 2006 (forthcoming)).

[12] This additional refund scheme reduced the average CO_2 tax burden to around 35% of the standard rate, i.e. a rate of 35 DKK per ton of CO_2 (Ministry of Finance 1995).

increases and introduction of energy taxes (a reform of the industrial CO_2 taxation and implementation of an SO_2 tax[13] and natural gas taxation in 1996).

  - o Industry was the main target in the Phase II of the Danish ETR. The main economic instruments used in this tax shifting programme are carbon dioxide and sulphur taxes levied on industrial energy consumption.
  - o Refund scheme for industry underwent a major overhaul. Industrial energy consumption is subdivided into three components: space heating, light and heavy process. The rationale behind this reform process was the aim that industry should pay the same energy tax rates than households. This was partly achieved because industry faces the same tax burden on energy used for space heating; i.e. industry pays the full energy as well as the full CO_2 tax rates. However, energy used for activities other than space heating is still fully exempt from energy tax and a reduced CO_2 tax rate is levied differentiated according to the actual purpose (see below for further information).
- The 1998 Tax Reform/Phase 3: period 1999 – 2002
  - o The tax shift programme is planned to be revenue positive in the range of around 6.4 billion DKK over the period 1999 – 2002, although it is expected that the 1998 Reform should be revenue neutral in the long-run. The total amount of 6.4 billion DKK accounts for around 0.3% of GDP in 2002 (see Table 4.2).
  - o Tax shifting programme: Increase in environmental taxes and corporate taxes to be used for reduction in personal taxes and taxes levied on the yield of pension savings and in addition a tax on share yields (corporate taxes).
  - o Biggest share of additional revenues raised should come from environmental taxes: Energy tax rates were increased during this period – increase between 1999 and 2002 around 5-7% for petrol, light fuel oil and heavy fuel oil but 16% for diesel, 12% for coal, 15% for electricity and natural gas by 33% (nominal terms - see Tables A1).
  - o This tax shifting programmes targets primarily the household sector because energy taxes were increased. Industry is only partly affected because industrial energy consumers are paying energy taxes only on energy products used for space heating; energy products used for other purposes are still exempt from energy taxation.

All these tax shifting programmes have been designed to be revenue neutral although the last reform process should only guarantee revenue neutrality over a time period which itself was not clearly determined.

4.1.1 The recycling measures of the different ETR phases

4.1.1.1 Phase I – 1994 - 1998

The first ETR implemented in Denmark concerned mainly households. The political objective underlying this tax reform was to bring down the marginal tax rates on personal income.[14]

4.1.1.2 Phase II – 1996 - 2000

The business sector was not affected by the 1993 Tax Reform and revenues were therefore recycled back to households. However, the government already announced at that time that new environ-

[13] Energy products are subject to SO_2 taxation and the tax has to be paid by industry and household. The SO_2 tax is levied according to the sulphur content.

[14] See for a discussion on how the marginal tax rates on wage incomes have been developed in Denmark: Jensen 2001, especially Table 2.

mental taxes would be introduced targeting industry. An inter-ministerial committee was established which recommended an increase of the CO_2 tax rates paid by industries, to differentiate the tax rates according to energy intensities and to make suggestions how to recycle back the revenues to industry.

The main recycling mechanisms to industry adopted have been:

(i) the provision of investment grants for energy-saving measures;

(ii) to recycle a fraction of the revenues to private enterprises compromising two elements:

- reduction of the employers' contribution to the additional labour market pension fund: reimbursement amounts to 1,325 DKK; (177 EUR) per year and per employee in 1996 compared to 1,166 DKK (156 EUR) in 1995;
- reduction of employers' contribution according to the Act on labour market funds: contribution will be lowered by 0.11 percentage units in 1997, 0.27 percentage units in 1998, 0.32 percentage units in 1999 and 0.53 percentage units in 2000;

(iii) the establishment of a special fund for small and medium sized enterprises because it was expected that small and medium sized enterprises will only receive a small share of measure (ii).

An overview of the expected revenues generated and distinguished between industry and households as well as the recycling mechanisms are illustrated in Table 4.1.

Table 4.1 Phase II of Danish ETR 1996 – 2000

	1996	1997	1998	1999	2000
Total tax revenue collected	915	1,440	1,955	2,220	2,450
Industrial and commercial sectors	710	1,230	1,730	1,900	2,075
- Space heating	420	750	1,050	955	910
- CO_2 tax	65	245	425	585	775
- SO_2 tax	225	235	255	360	390
Households	205	210	225	320	375
Revenue recycled					
To trade and industry	710	1,230	1,730	1,900	2,075
- Investment subsidies	300	500	500	500	0
- Small businesses	180	210	255	255	295
- Reductions in employers' SSC	200	490	945	1,115	1,750
Administration costs	30	30	30	30	30
*Compensation to electric heating users**	60	60	60	60	60
To households	145	150	165	240	315

Notes: * Subsidies for conversion to electric heating; revenue figures as planed as of 1995 in million DKK
Source: Hansen J. H. H. 1999.

It is noteworthy that the proposed recycling mechanism clearly reflects the contribution of the two different economic sectors. Industry and households are receiving the amount back which they are expected to be paying as a consequence of the reform process, i.e. no cross-subsidisation of any type should occur. This Danish approach of a fair and equal distribution of revenues has to be seen and compared with the German approach as discussed in Chapter 4.3.

4.1.1.3 Phase III – 1999 - 2002

The 1998 Tax Reform affected again mainly the household sector (Larsen 2002). The expected results with regard to the tax shifting programme are shown in Table 4.2.

Table 4.2 Denmark's Green Tax Shift Programme – Third Phase 1999 - 2002

	1998	1999	2000	2001	2002
Personal taxes	0	1	-0.1	-2.9	-6.2
Green taxes	0.6	3.1	3.9	4.8	5.6
Taxes on yield on pension savings	0	-1.1	-3.7	-3.7	-3.8
Corporate taxes	0.8	1.9	2	2	1.9
Total	1.4	4.9	2	2	-2.5

Note: forecasts for 1999-2002 in billions DKK
Source: Jensen A. H. 2001.

The reduction in personal income taxes mainly affected lower and medium income owners and it also included compensation for pensioners. As mentioned above the main revenue raising policy was to increase solely energy tax rates and not CO_2 tax rates. This is insofar of significance because the business sector is not too affected when energy taxes are being increased because of special tax provisions (see for further information: Jensen 2001).

4.1.2 Industry – special tax provisions

Industry benefited from favourable energy tax provisions for a long time. This sector was not subject to any taxes levied on energy products until the introduction of the CO_2 tax in 1992. Between 1993 and 1995 enterprises were subject to 50% of the standard CO_2 tax and in addition energy intensive industries were eligible for a special CO_2 tax refund scheme depending on the CO_2 tax liability as measured with respect to value added (Nordic Council 1994, pp. 66-67 and Ministry of Finance 1995).

The scheme of special tax provisions for industry changed in 1995. Companies are paying CO_2 taxes according to different type of usage. A differentiation between space heating – the full CO_2 tax rate applies – and process purposes which are further distinguished between heavy and light processes. Process energy is generally exempt from any energy taxes.

In general, energy consumed in processes other than space heating are levied with a CO_2 tax rate which increased gradually from 50 DKK per ton CO_2 up to 90 DKK per ton CO_2 in 2000. Companies entering an agreement with the Danish energy authorities on increasing the energy efficiency are eligible for a reduction in the CO_2 tax rate as illustrated in Table A4-1c.

The Danish government developed the so-called 'Proms-criterion' – defining whether process is energy-intensive – and whether the CO_2 tax rate is therefore further reduced. Based on this list[15] a process is designated to be energy intensive if '*the liability incurred on the process through a tax of DKK 50 per tonne CO_2 will permanently exceed 3% of added value while the liability simultaneously exceeds 1% of sales*' (Ministry of Finance 1995, p.14). Energy used in such heavy processes is subject to an even more reduced CO_2 tax rate as shown in Table A4-1c.

Interesting to note is the fact that the standard CO_2 tax rate of 100 DKK per ton CO_2 has not been increased since the tax was implemented in 1992. The CO_2 tax burden of industry increased gradually during the period of the second phase of the ETR (1996-2000) but remained then constant until 2004. In 2005 the nominal CO_2 tax rate of 100 DKK was reduced to 90 DKK per ton CO_2. However, this revision does not affect the effective tax rates paid by industries as the share has been increased proportionally so that the tax rate per ton CO_2 remains the same as before (Nordic Council 2006 (forthcoming))... This reduction in CO_2 tax rate was compensated by a slight increase in energy tax rates but which does not affect industry because this sector is still exempt from energy taxes apart from energy used for space heating. Although the effective tax rates are rather low, especially when compared to the high Danish nominal tax rates, they are still exceeding the minimum excise tax rates set by the European Union in the recently adopted Taxation of Energy Products Directive (Directive 2003/96).

Electricity consumption of the manufacturing industry is also subject to some special tax provisions. The standard Danish electricity tax differentiated between an energy tax components and a CO_2 tax component is one of the highest electricity taxes in Europe. The scheme applies a two-tier approach by distinguishing between electricity used for heating purposes and for all other uses. Furthermore, manufacturing industry enjoys some further tax provisions for the consumption of electricity for process purposes because of some favourable exemption rules. First of all, companies paid an energy tax rate of 10 DKK per MWh as compared to the standard rate of 566 DKK per MWh in 2004 and they are also eligible of a 40% refund on the CO_2 tax rate of 100 DKK per MWh. Therefore, the tax electricity rate paid by manufacturing industry amounted to 70 DKK per MWh as compared to 566.6 DKK per MWh in 2004, i.e. an effective tax rate of around 12% of the nominal tax rate. Furthermore, the reduced energy tax rate only applies to the first 15 million kWh consumed each year (Nordic Council 2006 (forthcoming)).

[15] The European Commission approved the process list as part of the overall Danish energy taxation scheme.

4.2 Finland

Finland was the first country in Europe introducing a CO_2 tax in 1990 levied on all energy products with the exception of transport fuels. Transport fuels were already subject to energy taxes in Finland at that time[16]. The Finnish CO_2 tax must therefore be perceived as an additional tax on energy products as it is the case in all EU member states discussed in this report.

The design of the CO_2 tax changed during its introduction several times:

- Between 1990 and 1994 the CO_2 tax was solely based on the carbon content of the energy product.
- From 1994 up to 1996 the design changed and the CO_2 tax was based on the carbon as well as on the energy content of the energy product; at the beginning 60 percent of the tax was determined by the carbon content and 40 percent by the energy content. This ratio changed to a 75/25 relation during this time period.
- In 1997, the design changed again and the CO_2 tax is a pure carbon dioxide tax since that year.

The CO_2 tax rate initially set to around 1.2 EUR per ton CO_2 in 1990 was regularly increased during the last 15 years and amounts to 18 EUR per ton CO_2 since 2003.

Some interesting development concerning energy taxation occurred in Finland during the last decade. Until 1997 Finland made use of an input tax scheme for electricity meaning that energy products used for electricity generation were subject to the standard energy taxes. This scheme was changed in the course of the liberalisation of the electricity market and because of inconsistencies of this tax scheme with the EC treaty. The new scheme introduced in 1997, is in line with an output taxation scheme, e.g. electricity generation is completely exempt from energy taxes and only electricity consumption is levied with an energy tax. A special tax condition affects natural gas because natural gas is subject to a reduced CO_2 tax rate, e.g. the tax rate is reduced by 50%.

The Finnish ETR reform process can be divided into two phases (Hoerner and Bosquet 2001):

- The first phase entered into force in 1997. From the beginning this tax shifting programme was not planned to be revenue neutral and the motivation of this programme was to reduce general tax revenues by 5.5 billion FIM (around 0.9% of GDP). The components of the programme have been
    - o The reduction in the state personal income tax amounting to 3.5 billion FIM and the reduction in employers' social security contributions and in the local personal income were around 2 billion FIM.
    - o This shortfall in revenues was partly compensated by revenues generated from the CO_2 tax and landfill tax. The revenues summed up to around 1.4 (1.1 and 0.3) billion FIM; i.e. 0.2% of GDP.
- The second phase was agreed to in late 1997 and implemented in 1998. Again the policy did not aim to be revenue neutral. The political objective of this programme was to further reduce labour taxes and to offset some of the deficit by increases in environmental taxes and corporate profit tax by broadening the tax base.
    - o Reduction in labour taxation as
        - ▪ Planned for 1998: 1.5 billion FIM.
        - ▪ Planned for 1999: 3.5 billion FIM, i.e. reduction of around 0.5% of GDP.

[16] Other oil products were subject to some form of environmental taxes in the form of an oil pollution fee and a precautionary stock fee at that time (Nordic Council 2006 (forthcoming)).

- The reform process anticipated a deficit of 1.5 billion FIM in 1998 and of 2.5 billion FIM in 1999. The underlying assumption of this policy of reducing taxes levied on the production factor labour was that it would lead to an increase in employment followed by an increase in labour related tax revenues.

The Finnish ETR affects both households and industry although the recycling measures are favouring the household sector. Furthermore, the Finish energy taxation scheme does not distinguish between different economic sectors with the exception of the electricity taxes which are discriminating between households and industry in the sense that industry faces a lower tax rate (see Table A4-2). Special tax provisions, such as reduction in energy tax rates and/or complete exemption from energy taxes, have never been implemented in Finish energy policy which on the contrary can be seen in the neighbouring Nordic countries as almost the standard. The only exemption is the case of electricity taxes and in addition energy products used as raw materials in the production process are exempt from any taxes. However, this policy is by and large the rule and not an exception in international energy policies and also in accordance with EU energy policy. The Finish energy taxation scheme of not granting special tax provisions to industry must however be assessed in the context that the nominal energy tax rates in Finland are generally lower than the nominal ones implemented in the neighbouring countries.

Nevertheless, energy-intensive industries are eligible for a refund mechanism which was first implemented in 1998 relieving these industries from some of the energy tax burden. The indicator assessing whether a company is energy intensive is different from the Danish approach insofar as the Finish indicator spells out that a company is then energy intensive if the energy excise taxes paid amount to 3.7 per cent of the value added of the enterprise but not taking into account taxes levied on motor fuels and any tax subsidies received. The qualified companies are eligible for a tax return of 85 per cent of the energy taxes paid – but the refund only applies if the tax liability exceeds 300,000 FMK. In 1999, 12 companies mainly from the paper and pulp industry were able to receive some reimbursement under this refund scheme and a total sum of 85 million FMK was refunded (Nordic Council 2002).

4.3 Germany

Although discussions concerning the potential of ETR already started in the early 1990s in Germany, an ETR was finally implemented in 1999. The German energy taxation scheme heavily relied on taxes levied on transport fuels as it is the case in all other European countries. However, some differences between Germany and the Nordic countries can be recorded as for example coal was never subject to energy taxes in Germany. Germany introduced an energy tax on natural gas in 1989. Noteworthy to note is the electricity taxation scheme until 1995. This tax scheme was known under the term '*Kohlepfennig*'. The revenues of this tax have been earmarked for the subsidisation of the German coal industry and the scheme was abolished in 1995. The tax was an *ad-valorem* tax and the rates were differentiated between industry and households (see the development of the main energy taxes in Table A4-3 in the Annex). The energy tax scheme experienced some major changes as part of the ETR.

4.3.1 The German ETR

The German government pursued to achieve two objectives when introducing the ETR in 1999:

- To improve environmental protection and in particular to reduce greenhouse gas emissions as a means of climate change mitigation.
- To reduce the employers' and employees' statutory pension contributions in order to reduce labour cost and to increase employment.

The ETR was implemented in two phases:

Phase I – 1999 - 2003

- The main policies have been an increase in existing energy taxes and the introduction of an electricity tax (see for a detailed overview: Table A4-3a in the Annex).
    - Mineral oil taxes on transport fuels (petrol and diesel) were gradually and steadily increased in five steps between April 1999 and 2003.
    - Taxes on natural gas and light heating fuels were increased in 1999 and another increase on the natural gas tax took place in 2003.
    - Taxes on heavy fuel oil were increased in 2000 and again in 2003. However, the tax on heavy fuel oil used for electricity generation was reduced in 2000 so that the heavy fuel oil tax is equal for all purposes.
    - Introduction of an electricity tax in 1999: The tax rate was gradually increased in five annual steps.
    - The increase in the tax rates for energy products other than transport fuels imposed on the manufacturing industry and the agricultural sector are lower than the standard increase because of the fear of hampering the competitiveness of German industry (see below for a more detailed discussion).
- The ETR was planned to be revenue neutral. But the German government refrained from this policy goal in the last years by using a small fraction (less than 10% of total revenue raised) for the consolidation process of the federal budget only as a temporary measure. The major share of the revenues are being used in a tax shifting programme by reducing employers' and employees' social security contributions (pension scheme) being paid by the two groups equally (i.e. in a 50:50 ratio). Furthermore, a very small fraction of around 1% has been earmarked for the promotion of renewable energy. The total volume of the tax shifting programme was 18.6 billion EUR in 2003 (around 0.9% of GDP). The adopted recycling mechanism resulted that the employers and employees pension contribution could have been reduced by 1.8% from 20.3% in 1998 to 19.5% in 2003. It is estimated that without the introduction of the ETR the total pension contribution would be in the range of 21.2% in 2003 as a consequence of the economic and demographic development in Germany.
- The German ETR approach is insofar interesting because of a slight inconsistency within the tax shifting programme. The main economic sectors affected by the revised energy tax schemes are household, transport and small and medium sized enterprises. But the main beneficiaries of the imposed recycling mechanisms are households and the industry as a whole.

Phase II – starting in 2004

- The German government wanted to extend the ETR to an Environmental Fiscal Reform by focusing on dismantling of environmentally harmful subsidies and other tax reductions and by adapting the heating fuel taxes on natural gas and on heavy fuel oil (as seen in Tables A4-3a and A4-3b in the Annex). The latter policies have been undertaken but the reform idea of having a major shake-up with regard to subsidies was abandoned because of political resistance, in particular of the opposition.

The total revenues raised by energy taxes under the umbrella of the ETR amount to around 18.6 billion EUR in 2003 and can be broken down to the individual tax as follows: 0.2 billion EUR revenue from the tax on heating oil, 3.4 billion EUR natural gas taxes, 6.5 billion EUR from the newly introduced tax on electricity, 2.4 billion EUR from tax on petrol and the major part of 5.7 billion EUR from tax levied on diesel (Cottrell 2004). The tax revenues imposed on energy products other than transport fuels capture around 10.5 billion EUR and approximately 60 percent of this sum is paid by households. Estimates are showing that around 88 percent of these revenues (9.2 billion EUR) are being used for recycling measures by reducing employers' and employees' pension contribution. The reduction in the two contributions is equally distributed (4.6 billion EUR) meaning that the industry is a net winner because industry contributes around 4.2 billion EUR effectively to this reduction (Cottrell 2004). The German ETR has achieved the underlying principle of an ETR namely the shifting of the tax burden from labour to energy use although slightly flawed benefiting mainly the industry. This favourable treatment of industries becomes more obvious when the special provisions with regard to the industrial energy taxation scheme are assessed.

4.3.2 Special Tax Provisions for Industry

Manufacturing industry, agriculture and forestry was granted special energy tax provision from the start of the ETR. Although the scheme was revised in 2003 the basic characteristics remained the same (Bach 2004).

- From 1999 until 2002:
    - Manufacturing industry, as well as agriculture, fishery and forestry sector was granted a tax relief of 80% for energy products (heating fuels, natural gas and electricity). The tax relief affected only the tax rates which were imposed as part of the ETR and were only available on the condition that the base amount (*'Sockelbelastung')* of 512.5 EUR per annum– electricity and heating fuels - was exceeded.
    - The manufacturing sector was eligible for an additional tax option – companies could apply for a tax cap ('*Spitzenausgleich*'). If the tax burden from increased energy tax rates was 20 percent higher than their tax relief from the reduction in pension contributions, companies were refunded the full differential amount. The outcome of this provision was that some industries had an effective tax rate of zero percent.
- From 2003 onwards
    - The tax relief for the manufacturing sector, agriculture, fishery and forestry was reduced. All companies of these sectors have been granted a tax relief of only 40 percent of the standard energy tax rates for electricity, heating oil and natural gas but only for energy consumption exceeding the base amount (*'Sockelbelastung')* which have been kept constant. However, only the increase in energy tax rates as a result of the ETR are reduced, i.e. the increases in the tax rates which took place since 1999. This policy change means that the effective tax rate is now 60 percent of the standard rate as compared to a meagre 20 percent between 1999 and 2003 (see Table A4-3d in the Annex).
    - In addition, the additional tax option is still applicable to the manufacturing industry but it was slightly revised. The new rule stipulates that a company is eligible for a refund if the energy tax burden is greater than its tax relief from the reduction in the pension contributions payable by the company. However, the refund currently amounts only to 95 percent of the differential amount. The outcome of this revision is that companies which are receiving the tax refund are now facing a tax rate of three percent as compared to the zero percent rule under the 1999 regulation. For example, the standard electricity tax rate in 2004 was 20.5 EUR/MWh. Companies which are statistically classified as manufacturing industries, agriculture, fishery and forestry business are facing an effective tax rate of 60% of the standard rate, i.e. the electricity tax rate amounts to 12.3 EUR/MWh. Companies of the manufacturing industry are facing an even lower effective tax rate of 0.62 EUR/MWh but only when they qualify for the '*Spitzenausgleich*' regulations.

Additional special tax regulations do exist but they are not specifically directed to address competitiveness concerns of industry. These provisions are mainly done for environmental reasons by either promoting renewable energies or by promoting improvements in energy efficiency:

- o Highly efficient CHP facilities with a monthly or annual utilisation rate of 70% or more are fully exempt from the mineral oil tax.
- o Mineral-oil-fired systems using at least 60 percent of the energy in mineral oil are partly exempted from the energy taxes (refund of 3.66 EUR/MWh for natural gas (effective rate: 5.5 EUR/MWh) and 20.5 EUR/1000 litres for light fuel oil (effective rate: 61.4 EUR/MWh).
- o Biofuels are fully exempt from mineral oil taxation. This regulation will keep in place up to 2009. It applies to all bioheating fuels, to biogas and synthetic petrol and diesel fuel produced from solid biomass, to bioethanol, biomethanol and hydrogen from biomass and to all admixtures
- o Electricity generated from renewable energies – generated solely with windpower, hydropower (but only for generators with power capacity below ten megawatts), solar power, geothermal power, landfill gas, sewage-treatment gas or biomass – is exempted from the electricity tax.

The German system of energy taxation, in particular introduced as a component of the 1999 ETR process, includes a whole range of special tax provisions for the manufacturing industry as well as for the agriculture, forestry and fishery sector. However, the exact design is rather different from the Danish system because the German regulations are applicable to all companies belonging to the statistical classifications which is in contrast to the Danish case where special tax provisions are only granted to specific defined production processes – not considering the fact that industry is subject to paying energy taxes only for fuels used for heating purposes. The German scheme is furthermore interesting because the clear division between economic sectors targeted via an increase in energy taxes and the sectors directly benefiting from the recycling measure has been abolished. This issue must be perceived of central significance because the overall tax burden of the manufacturing industry has been lowered as a result of the tax shifting programme.[17] However, the German scheme of granting tax reduction to manufacturing industry as a whole was approved by the European Commission in 1999 but must be revised latest until the end of 2006. The tax exemptions granted to the manufacturing sector qualify as state aid for environmental protection and they are in accordance with EU law, in particular they do not oppose the community guidelines on competition. EU law allows the provision of tax exemptions if the affected sector requires 'temporary relief' from environmental taxes.

4.4 The Netherlands

The Dutch government was one of the forerunners in Europe with regard to the implementation of energy taxes. Until 2004, four different energy taxes were imposed on the consumption of energy products: the environmental tax on fuels (also called general energy tax or C general), the regulatory tax on small scale consumers (also celled energy tax or C limited), the excise/energy tax as well as a parafiscal tax, strategic stockpile fee (the so called *cova levy* on petrol, diesel, gas oil, LPG and kerosene).

In 1988, the government introduced a general fuel charge which was revised several times. This general fuel charge replaced a whole system of programme-specific and earmarked levies in the areas of waste, water, noise, etc. A further revision took place in 1991 when the general fuel charge

[17] See for an ex-ante analysis of the consequences of the German ETR illustrating that German industry will be a net winner of this reform: Hillebrand 1999.

was adjusted to the environmental tax on fuels. The revenues generated by the environmental tax on fuels are no more earmarked but part of the general budget. The tax is levied on all energy products which are used as fuels. This means that use of energy products as raw material and feedstock is exempt from the tax as well as coal and natural gas used for electricity generation is also exempt from the tax since 2001. The last revision of this tax took place in 2004 when the tax on all energy products - other than coal - was incorporated into the energy/excise taxes.

The tax base was also subject to several revisions during the 1990s. A CO_2 component was added to the tax base in 1990 and this was revised in 1992 when a new tax scheme was introduced based on the energy and carbon content of the energy products. Starting with 1999 the tax rates of all energy taxes are indexed according to the inflation (see the development of energy tax rates in the Netherlands: Table A4.4 in the Annex).

In 1996, the regulatory energy tax on small scale consumers was introduced. This tax is levied on mineral oil products not used for transport purposes, natural gas and electricity. The purpose of this tax was to stimulate energy efficiency improvements among small energy consumers. The revenues of this tax are recycled back to the economy as part of the Dutch ETR. Competitiveness considerations have been seriously taken into account when the tax was designed. The rationale behind the tax exemption of large industrial energy consumers was the potential risks of harming their export competitiveness when introducing such a tax unilaterally.

Energy consumed was only taxed up to a ceiling and in addition every consumer received a tax free allowance (natural gas and electricity). Because of institutional problems of administering tax free allowance of non-metered mineral oil products the tax rates have been lowered accordingly. The tax free allowance have been repealed in 2001 and replaced by a fixed tax reduction per electricity connection. This tax reduction was 141 EUR per year in 2001 and increased to 194 EUR in 2005. Furthermore, the specific rule regarding the ceilings has been abolished as a consequence of the adoption of the EU Energy Tax Products Directive in 2004. Energy consumed above the ceilings is now levied with the energy tax but the rates levied on the mineral oil products are around 10 percent of the standard rate.

A specific characteristic of the Dutch energy taxation scheme is the tax differentiation of the natural gas and electricity as shown in Tables A4-4a and b in the Annex.

4.4.1 ETR in the Netherlands

In 1998 an ETR was implemented in a revenue neutral way and the revenues raised by the regulatory energy tax provides the biggest fraction. All revenues are recycled back to the economy (households and industry) applying different recycling measures in 1999:

- Households: economic, social and demographic aspects of households have influenced the recycling measures.
    - a 0.6 per cent reduction in the rate charged over the first income bracket;
    - a raise of the tax free allowance by 80 HFL; 36.3 EUR; and
    - a raise in the standard deduction for senior citizens by 100 HFL; 45.4 EUR.
- Industry: there are different recycling options in place depending on the types of business.
    - via a reduction of 0.19 per cent in the wage component paid by employers;
    - a raise in the standard deduction for small independent businesses (tax credit for self-employed people is raised by 1,300 HFL; 590 EUR); and

    - a reduction of 3 per cent in the corporate tax rate over the first 100,000 HFL; 45,378 EUR.
- The revenues raised by these taxes levied on energy products amounted to 3.2 billion EUR, around 0.7% of GDP in 2001.

4.4.2 Special Tax Provisions for Industry

The Dutch energy taxation scheme follows the schemes implemented in other EU member states by granting tax provisions to industry. However, the Dutch government perceives energy taxes as one of whole set of policy instruments addressing energy policy issues. Environmental agreements completed between the government and large scale energy consuming industries committing themselves to improve their energy efficiency are of central significance in the Netherlands. These long term agreements with regard to energy conservation measures are further strengthened by provisions established in environmental permits.

The specifics of the Dutch energy tax scheme are the tax differentiation with regard to the consumption level concerning natural gas and electricity. These detailed tax rate differentiations are unique in EU member states considering that tax rates for natural gas are differentiated between seven consumption levels and six levels for electricity. This approach of tax differentiation based on the energy consumption (so-called volume zones in the case of natural gas[18]) differs from the German case where all manufacturing industries – based on statistical classification and not based on the actual consumption level – are eligible for a reduced tax rate. The changes occurring during the last years in the Dutch energy taxation scheme were mainly a consequence of EU policies in the area of energy and state aid / competitiveness. For example, the European Commission allowed the Dutch government to apply a zero rate on natural gas used in greenhouses until 1999. Nowadays the greenhouse horticulture sector is facing a rather low tax on natural gas. Furthermore, mineral oil products used for purposes other than transport are subject to a two-tier tax system. All mineral oil products exceeding a certain predefined ceiling were also subject to a zero tax rate (regulatory tax rate) until 2004, although the full energy/excise tax rate applied. Since 2004 a reduced tax applies to mineral oil products exceeding the ceiling.[19] Fuels used for electricity generation are exempt from energy taxation just as in other EU member states.

The Dutch ETR addresses both households and industry which is also reflected in the recycling measures adopted. However, revenues raised by taxes levied on transport fuels are not used for the tax shifting programme in the Netherlands as it is the case for example in Germany.

4.5 Slovenia

The development of energy taxation in Slovenia shows some interesting features although an ETR has not been introduced. Nevertheless it is worthwhile to assess the situation as during the last 15 years the system of energy taxation experienced some fundamental changes. Until 1997 energy products were subject to an *ad valorem* tax ranging from 5 percent for natural gas, wood and district heat, a 10 percent rate for electricity and coal and 20 percent for fuel oil and all other non transport fuels (a higher rate of 32 percent applied to high sulphur fuel oil). The tax rates for transport fuels were much higher amounting to 90 percent for unleaded petrol, 140 percent for leaded petrol und 190 percent for diesel. The rates of the *ad valorem* taxes have remained constant since the early 1990s and have been abandoned in 1997 for almost all energy products with the exception of these taxes levied on transport fuels which have finally been discarded in 1999.

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[18] Gas prices paid by consumers are around 0.25 EUR per m3 in the first zone (consumption up to 170,000 m3 per annum), 0.13 EUR per m3 in the second and 0.11 EUR in the third zone.

[19] The effective tax rate (regulatory tax) is around 10 percent of the standard regulatory tax rate which is applicable to the consumption of mineral oil products below the threshold.

A new system of taxation came into force in 1997, and respectively in 1999 when the act on value added tax and on excise taxes was adopted by the Slovenian Parliament. Since then the excise taxes are on the basis of *ad quantum* taxes. However, this change was accompanied with a reduction of taxable energy products; i.e. only light fuel oil was subject to an excise tax in 1997, the year 1999 marks the start levying the excise tax on transport fuels (petrol and diesel) and in 2000 the use of natural gas was subject to an excise tax.

As Slovenia joined the EU in 2004 the EU minimum excise rates established under Taxation of Energy Products Directive (2003/96/EC) are also valid in Slovenia. However, Slovenia as all other new EU member states may apply temporary exemption of reductions in the levels of taxation as laid down in the European Council Directive (2004/75/EC) amending the Taxation of Energy Products Directive.

Another feature of the Slovenian energy taxation scheme is interesting as Slovenia was the first country of Eastern and Central Europe introducing a CO_2 tax. This tax was implemented in 1997 and applied to all energy products. However, coal used for electricity production was exempt from the CO_2 tax until the end of 2003. The tax base is a pollution unit and defined as emissions of 1 kg CO_2 emissions meaning that the actual CO_2 tax rates are depending on the carbon content of the energy products. Initially the tax rate was 1 SIT per kg CO_2 (4.2 EUR per ton CO_2) and was raised to 3 SIT per kg CO_2 (12.5 EUR per ton CO_2) in 1998. Since then the rate was kept constant. An interesting feature of the CO_2 taxation scheme was adopted at the beginning of 2005 when the Slovenian Government exempted the country's biggest CO_2 emitting companies from the CO_2 tax burden if these companies are covered under the EU emission trading scheme (ETS) (Máca et al. 2005). This development is of relevance for the discussion on energy taxation and competitiveness as other countries, such as Denmark and Sweden, are thinking to follow this approach in due course (Nordic Council, 2006 (forthcoming)). However, the principle of exempting manufacturing sectors from all energy and CO_2 taxes in the case that these sectors are part of the emission trading regimes addresses some sensible issues with regard to the state aid rules.

The revenues generated by the CO_2 tax are not hypothecated although plans were drawn up that around one third of the revenues (around 5 billion SIT) should be used for co-financing investments promoting an increase in energy efficiency and a reduction of CO_2 emissions in 2004. Revenues generated from other environmental taxes, such as water consumption tax, waste taxes, etc., are usually earmarked for specific environmental investment programmes (Máca et al. 2005).

Special tax provisions have also been implemented in the Slovenian CO_2 taxation regime as companies may be eligible for tax reduction amounting up to 100 percent. However, the scheme is digressive as the reduction decreases by 8 percent per annum until the end of the scheme in 2009.

4.6 Sweden

The Swedish energy taxation scheme is very comprehensive consisting of four different types of taxes. Apart from the traditional energy/excise taxes levied on energy products – mainly mineral oil products – the Swedish government introduced in the early 1990s CO_2 taxes (1991), SO_2 taxes (1991) and a NO_X charges (1992)[20]. Since 1995 energy taxes are indexed and linked to CPI in Sweden.

[20] The SO_2 tax as well as the NO_X charge are not discussed in detail – see for further information on these instruments: Nordic Council 2002 and 2006 (forthcoming).

The scheme shows some rather interesting features because the scheme has been advanced during the last 15 years sometimes as a direct consequence of issues related to the fear of harming the competitiveness of Swedish industry. The most striking feature was the introduction of the CO_2 tax in 1991. Special tax provisions have not been granted to Swedish industry at that time leading to a significant increase in the overall tax rate, in particular for energy products other than transport fuels (see Table A4-6 in the Annex). The introduction of the CO_2 tax was slightly compensated by a reduction in the energy/excise taxes. However, a refund mechanism was in place which limited the total energy tax burden paid by industry (see Chapter 4.6.2 for a detailed discussion). The tax scheme was revised in 1993 so that manufacturing industry was completely exempt and paid only a fraction of the CO_2 tax rates (see Table 4-6a in the Annex) reducing the tax burden of manufacturing industry quite dramatically when comparing the situation of 1992 with 1993. A similar tax switching policy has been implemented in 2000 with reducing the energy/excise tax rates and increasing the CO_2 tax rates overcompensating the reduction with the result of an increase in the overall energy tax rates. It is further worthwhile to mention that industry was exempt from paying taxes levied on the consumption of electricity during the period 1993 and 2003. The decisive factor of abolishing this regulation was the EU Energy Product Tax Directive setting minimum tax rates on electricity consumption.

4.6.1 ETR in Sweden

Sweden embarked on two major fiscal reform processes since the 1990s and ETRs were part of these reform processes.

- The fiscal reform process in 1991 – the first major ETR in Europe:
  - The overall objective of the 1991 fiscal reform process was the reduction of personal income taxes by about 71 billion SEK (to be around 4.6% of GDP in 1991). Income tax rates were cut to around 30% (average rate) and to around 50% for high income earner.
  - The shortfall in total revenue was partly compensated by levying the value added tax (VAT) on energy purchases and by introducing the SO_2 and CO_2 tax in 2001.
  - Revenues raised by environmental taxes were increased by 18 billion SEK (to be around 1.2% of GDP in 1991). This fiscal reform process was not intended to be revenue neutral. However, the ETR component offset some of the shortfall within the national budget.
- The second ETR is again part of a major fiscal reform process planned to be implemented during the ten year period 2001-2010:
  - The Swedish government aims to lower taxes paid by low and medium wage earner, and to encourage the adjustment to an ecologically sustainable society (Swedish Government 2002). As part of this reform process the government intends to increase revenues generated from environmental taxes by up to 30 billion SEK during the ten year period (the so called green tax shift programme). These revenues are being used for budget consolidation as a consequence for the reduction in income taxes.
  - During the first four years of the programme (2001-2004) a shift of 10 billion SEK have been implemented so far (to be around 0.4% of GDP) and a further shift of 3.8 billion SEK is planned for 2005.
  - As the ETR is part of a major overhaul of the fiscal system, budget revenue neutrality was never seen as an aim to go for. For example, the 2005 budget predicts a shortfall of around 8.2 billion SEK; revenues from taxes on income from work are to be lowered by 10 billion SEK and from taxes of capital and companies by 1.9 billion SEK.

The 2004 budget intended to go ahead with a tax shifting programme amounting to 2 billion SEK via the increase in environmental taxes and by cutting income taxes and social insurance contributions benefiting households as well as industry. For 2005 the planned tax shift programme accounts for to an increase in environmental taxes of around 3.8 billion SEK which will offset only a part of the shortfalls in tax revenues as a consequence of reductions in labour and capital taxes amounting to around 12 billion SEK. A further increase in environmental tax revenues of about 3.6 billion SEK is planned for 2006 (Swedish Budget 2005).

Table 4.3 Tax shifts in the Swedish budget in 2004 (million SEK)

Tax	Reduction	Increase
Income tax	1,360	
Social insurance contributions	640	
Carbon dioxide tax		820
Tax on diesel		270
Electricity tax (industrial users – applied as from 1 July 2004)		90
Electricity tax (households, other business users)		770
Tax on pesticides		13

Source: Swedish Budget 2004

Both major fiscal reform processes are aiming to reduce the tax burden of all sectors of the economy. The increase in environmental taxes are also affecting all sectors although the effective tax rates levied on energy consumption by the manufacturing industry have not been increased in the same range than the standard energy taxes which are being paid by households.

4.6.2 Special Tax Provisions for Industry

The Swedish approach of granting special tax provisions to industry passed through different stages.

Until 1992 Swedish industry did not receive any special treatment concerning energy tax rates, e.g. industrial energy consumption was subject to the same tax rates as all other economic sectors. However, the total energy tax burden had a ceiling meaning that the energy tax bill of a company could not exceed 1.7 percent of the sales value. The policy refunding the difference between the energy tax bill and the sales value were valid for until the end of 1991 and the maximum amount of energy taxes to be paid by individual companies was reduced to 1.2 percent of sales value in 1992. The ceiling of 1.2 percent remained in place also in the following years. In addition, to the refund mechanism Swedish manufacturing industry was granted a generous tax package because this sector was completely exempt from paying energy taxes and was subject to be paying only a fraction of the CO_2 taxes starting in 1993 (see for an overview of tax rates applicable to manufacturing industry: Table A4-6a in the Annex). This regulation is still valid but the fraction of the CO_2 tax rate payable by industries has been revised frequently:

From 1993 onwards the industry does not pay energy tax but

- 25 percent of the CO_2 tax between 1993-1997,
- 50 percent of the CO_2 tax between 1998-2000,
- 35 percent of the CO_2 tax in 2001,
- 30 percent of the CO_2 tax in 2002,

- 25 percent of the CO_2 tax in 2003,
- 21 percent of the CO_2 tax in 2004 and 2005.

Particularly interesting is to assess the development of the tax rates for the manufacturing industry because the tax rates for this sector increased between 1998 and 2005 by a meagre 3 percent in nominal terms as compared to an increase of between 85 percent (light fuel oil and heavy fuel oil) and around 110 percent (coal and natural gas) of the overall tax burden (energy plus CO_2 tax rates). The offset of these big increases in nominal tax rates is compensated by revising the fraction of the CO_2 taxes actually to be paid by companies, i.e. this fraction dropped from 50 percent in 1998 to 21 percent in 2004.

In addition to this provision of granting generous tax rebates energy intensive companies are eligible for a refund scheme when their CO_2 tax liability exceeds 0.8 percent of the value of sales. In this case the company was entitled to a tax reduction so that only 12 percent of the excess tax burden is to be paid. The refund scheme is also regularly amended. Currently companies are entitled to a tax reduction but have to pay up to 24 percent of the excess tax burden when the CO_2 tax burden exceeds the 0.8 percent limit. It is predicted that around 50 companies are eligible for the refund. The most energy intensive companies facing a carbon tax bill amounting to over 1.2 percent of the sales value are exempt from paying any tax for the excess amount.

The same policy of granting a tax free status for energy products used for electricity generation is in place in Sweden as compared to other EU member states. However, this policy does not apply with regard to the SO_2 tax, e.g. energy products used for electricity production are liable to the SO_2 tax.

4.7 The UK

The UK energy tax structure is rather simple when compared to the schemes implemented in the Nordic countries. The scheme heavily relies on the energy/excise taxes levied on transport fuels, in particular, with regard to the revenue generated from these taxes. The UK has by far the highest transport fuel taxes in Europe and in the world which can be attributed to the road fuel escalator of the 1990s (Ekins and Speck 2000, EEA 2005 (forthcoming) – see for an overview of the development of UK tax rates: Table A4-7 in the Annex*)*. A general scheme of energy taxes levied on other energy products does not exist in the UK.

In 1990 the UK government introduced the Fossil Fuel Levy (FFL). The FFL was levied on the purchase of 'leviable electricity' and all consumers faced this levy, i.e. the FFL is a tax on electricity. The design of this tax differs because it is an *ad valorem* tax. Initially the majority of the revenues raised by the FFL have been used to subsidise nuclear power and only a smaller fraction has been earmarked to support renewable[21]. At the end of 1998 the nuclear industry did not receive anymore subsidies raised by the FFL. Instead the FFL revenues have been utilised to support projects with renewables under the Non-Fossil Fuel Obligation (NFFO). The levy reached its peak in 1992 when the rate was 11% of the end-user electricity price (excl VAT) and the rate is set to 0% since 2003. It is noteworthy to record that the zero percent rate does not mean that the FFL is abolished.

A new economic instrument was introduced by the UK government in April 2001. This new instrument, the Climate Change Levy (CCL), applies only to non-domestic use of energy (commercial and industrial use). Since 2001 the consumption of natural gas, electricity and coal is subject to the CCL and the consumption of LPG is subject to the CCL in addition to the existing energy/excise tax. The revenues generated by the CCL are used for a tax shifting programme (ETR) in the UK.

[21] See for example for more information: http://www.bwea.com/ref/nffo.html

4.7.1 ETR in the UK

The UK launched three ETRs within the last decade:

- First ETR
    - Introduction of the landfill tax in 1996.
    - The principle of revenue neutrality has been followed up. Revenues raised by the landfill tax are being used for reducing employers' social security contributions (SSC). In addition, a small fraction of the revenues are being used for establishing of a special fund. The fund supports investment in waste related issues as well as research activities in the waste field.
    - The total tax shift is rather modest and amounts to 0.05% of GDP in the fiscal year 2004/2005.
- Second ETR
    - Introduction of the climate change levy in April 2001.
    - Again the principle of revenue neutrality is adhered and the major part of the revenues is used for lowering employers' SSC. The remaining part is utilised to set up the Carbon Trust. This fund again assists investment in energy issues and research activities.
    - The dimension of the tax shifting programme is around 0.06% of GDP (2004/2005).
- Third ETR
    - The so far latest ETR took place in 2002 when the UK government introduced the aggregates tax.
    - The third ETR follows exactly the first and second tax shifting programmes in the way that the revenues generated by the aggregates tax compensate the reduction in employers' SSC and to establish the special fund ('Sustainability Funds').
    - The pure size of the third ETR is extremely small amounting to around 0.02% of GDP (2004/2005).

All three tax shifting programmes implemented in the UK have in common that they are directly targeting businesses and not the household sector. Therefore it is not surprising and quite logical that the same recycling measure applies in the form of reducing the social security contributions which employers (i.e. businesses) have to pay with the aim to guarantee that the total tax burden of the industry as a whole remains the same. But this policy clearly causes that the tax liability of different industrial sectors is affected differently, i.e. some sectors are net winners and others are net losers.

4.7.2 Special Tax Provisions for Industry

Some form of granting special tax treatment is also part of the Climate Change Levy (CCL) scheme. Energy intensive companies are eligible for an 80 percent tax discounts when agreeing to stringent energy efficiency improvement targets. These regulations have been introduced because of concerns of losing of international competitiveness of the UK industry as a consequence of the introduction of the CCL. The approach chosen by the UK government was to give conditional tax exemptions to energy intensive companies. The concept behind this approach is that companies are facing a reduced tax liability when they enter into legally binding Climate Change Agreements (CCA) requiring adoption of energy saving reduction programme (OECD 2005). Rather interesting is the approach selected in the UK of confining the term energy intensive industries. It was decided that this policy is limited to those energy intensive industries which are already registered as energy intensive under the EU Integrated Pollution and Prevention Control (IPPC) Directive. This is insofar interesting because the approach clearly limits the special tax provisions to really energy intensive industries as compared to the German situation where the selection process of which industries are eligible for special tax treatment is based on statistical classification. The German approach must be challenged because the concept of using statistical categories as the basis for providing tax relief does not take into account the issue of energy intensity. The consequence of this approach is that companies can disproportionately profit from the ETR as they are entitled to tax relief although they cannot be described as energy intensive.

5 Conclusions

Although the underlying reasons for implementing ETRs in EU member states are alike, the design of these tax shifting programmes differ. Design issues vary depending on the affected economic sectors as well as adopted recycling mechanism. However, the various reform processes have in common addressing multiple political objectives leading to an improvement in environment (an environmental benefit) and support for employment (an economic/employment benefit). Problems and discrepancies emerge when analysing the effects of ETRs in more details as such assessments crucially depend on the benchmark.

Owing to various reasons, theoretical considerations are regularly not accounted into the actual design of an ETR. Maybe the most striking example is the revenue neutrality principle as political reality demonstrates (see the overview table in Annex 2) although it is often portrayed as the rationale of this reform process. However, revenue neutrality is only a choice and cannot be achieved when an ETR is part of a much larger fiscal reform process as it is for example the case in Sweden. It seems that revenue neutrality is rather being seen as a presentational device reassuring the general public that this reform process will not increase the overall tax burden. It may also make some sense to have somehow a *weak definition* as opposed to a *strong definition* of an ETR. An ETR follows the latter approach if there is an explicit acknowledgement of a reduction in any other taxes as a consequence of the introduction of new or an increase in existing environmental taxes and under the condition that the national budget does not increase. This means that the explicit hypothecation of tax revenues is a necessary requirement under the *strong definition* of an ETR. Otherwise environment taxes could always be interpreted as part of an ETR as the revenues generated by them are always part of the national budget and can therefore be used for some form of changes in the overall taxation framework as it happened for example in Russia in 2001 when taxes levied on transport fuels have been increased dramatically (by up to 300 percent) and simultaneously capital and labour taxes have been reduced (EEA 2005 (forthcoming)). Interesting to note is the fact that these changes in the fiscal framework of countries are not necessarily explained using environmental reasons. Examples of such policies where the revenue loss following the reduction of distortionary taxes, such as the ones imposed on labour or capital, are being offset through increases in energy tax rates have also occurred in many other countries, such as the Czech Republic (Máca et al. 2005).

Special tax provisions granted to industries as a consequence of the potential fear of losing international competitiveness is one of them and contradicts conventional economic theoretical analysis. However, governments are facing political constraints and consequently have to trade off between economic efficiency arguments and the concept of political economy by considering other aspects, such as distributional deliberations, when making political decisions.

The overview of implemented tax shifting programmes in EU member states illustrates that the granting of special tax provisions is a phenomenon which has been further developed and elaborated during the last decade. This policy is a clear example of the political ambivalence because tax differentiations favouring manufacturing industries are contradicting economic efficiency arguments. However, political decision makers are confronted with the political reality and constraints, making it almost necessary to grant tax exemptions to manufacturing industries as a prerequisite to implement ETRs at all. Nevertheless, this policy can impair the achievement of the multiple political objectives because it can lead to excess costs because the cheapest emission reduction potential need not be exploited. Such a policy, in addition, requires that the other economic sectors face higher energy tax rates if a predefined emission reduction goal has to be achieved.

There is no doubt that energy taxes can have an impact on the competitiveness of energy-intensive industries although, the competitiveness depends on more factors then only on energy taxes. Firstly, other price factors such as import energy prices and transmission and distribution tariffs (natural gas and electricity) as well as exchange rate variations have some significance in this discussion. Secondly, non-price factors, such as production methods, infrastructure and education, are also important while thirdly and finally it is necessary to carry out a detailed analysis of the actual situation with regard to the energy tax burden versus the recycling measure introduced as part of an ETR.

Apart from earmarking some of the additional generated revenues for specific investment programmes to promote and support the energy efficiency improvements (Denmark, Germany and the UK) and reduction of capital taxes (the Netherlands and Denmark), the major part is being used for the reduction of taxes and charges levied on labour. EU member states made use of the following options:

- Reduction in income tax rates; this option is often used as a measure to compensate households for higher energy tax bill. However, businesses are not affected by this measure although political objective of this measure is to increase employment in the long-run. This policy option has been applied in Finland, the Netherlands and Sweden.
- Reduction in social security contributions which can be distinguished even further:
    - Reduction in employers' social security contributions; this policy will reduce labour costs paid by employers. Therefore it is the recycling option which is probably most in line with the political objective of reducing employers' labour costs as a condition for providing new jobs and hence to reduce unemployment.
    - Reduction in employee's social security contributions; this policy option affects employees as their net wage increases.
    - It is interesting to record that the policy option of reducing social security contributions is widespread in use in Denmark, Germany, the Netherlands, and the UK.
- The third and last option is lump-sum transfers to households. The underlying reason for adopting this policy, as implemented for example in the Netherlands, is to compensate the part of the society which does not pay income taxes or social security contributions but are facing higher energy bills (for example pensioners and students).

The policy decision of which recycling measures have been actually implemented in EU member states depends crucially on the economic sectors targeted by the ETR. The comparison between the German and the UK experiences with ETR illustrates this issue quite clear. All economic sectors, i.e. agriculture, industry, trade, public institutions as well as private households are facing a higher energy tax bill as a consequence of the ETR and all economic sectors have also been compensated in some form. The UK ETR is in clear contrast to the German ETR as it affects only industrial and commercial energy use and is therefore not surprising that only these economic sectors are benefiting from the recycling measures.

As discussed throughout the report special tax provisions for industries are implemented in EU member states. However, the concrete type of these tax provisions varies between countries, which make it difficult to provide an overview of effective tax rates industries are facing. The complex design of the country- as well as industry-specific tax provisions comprises straightforward reduced tax rates for industrial sectors (Denmark, Germany, the Netherlands, Sweden, and the UK) as well as some form of ceilings for the total energy tax burden for individual companies (Denmark, Finland, Germany, and Sweden). Only energy-intensive companies can benefit from the latter tax regulation as reduced energy tax rates can be applicable to the whole industrial sector, as in Germany, or to individual industrial sectors and companies - sometimes in combination with agreements requiring these companies to invest in energy efficiency improvements (the Netherlands and the UK). The tables presented in Annex 5 are comparing the nominal tax rates with effective tax rates and are only an indication of the tax rates industries are facing in the countries by considering the special tax regulations discussed in Section 4 of the report. Data presented in the tables must be treated with some caution, as the calculation of effective tax rates is not a trivial task owing to the complexity of the tax provisions. The most striking is the finding that the countries with the highest nominal tax rates (Denmark and Sweden) introduced wide-ranging tax provisions so that the effective tax rates facing industries in the selected EU member states are more similar than expected[22]. It is also noteworthy that the Finnish industry is facing the same tax rates as the other economic sectors with the exception of the taxes levied on electricity consumption.

[22] The Danish situation requires some specific attention because the effective tax rates depend on the actual energy usage. As illustrated in the tables of Annex 5 industry is facing three different energy tax rates and therefore it is not possible to determine an effective tax rates. However, the tables are showing that the tax rates for energy use in heavy processes are often the lowest as compared to the situation in other EU member states.

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Annex

Annex 1:

Tables 1: Overview of labour taxation-to-GDP (total taxation) ratio and environmental tax-to-GDP (total taxation) ratio for EU 15 and for the new EU member states

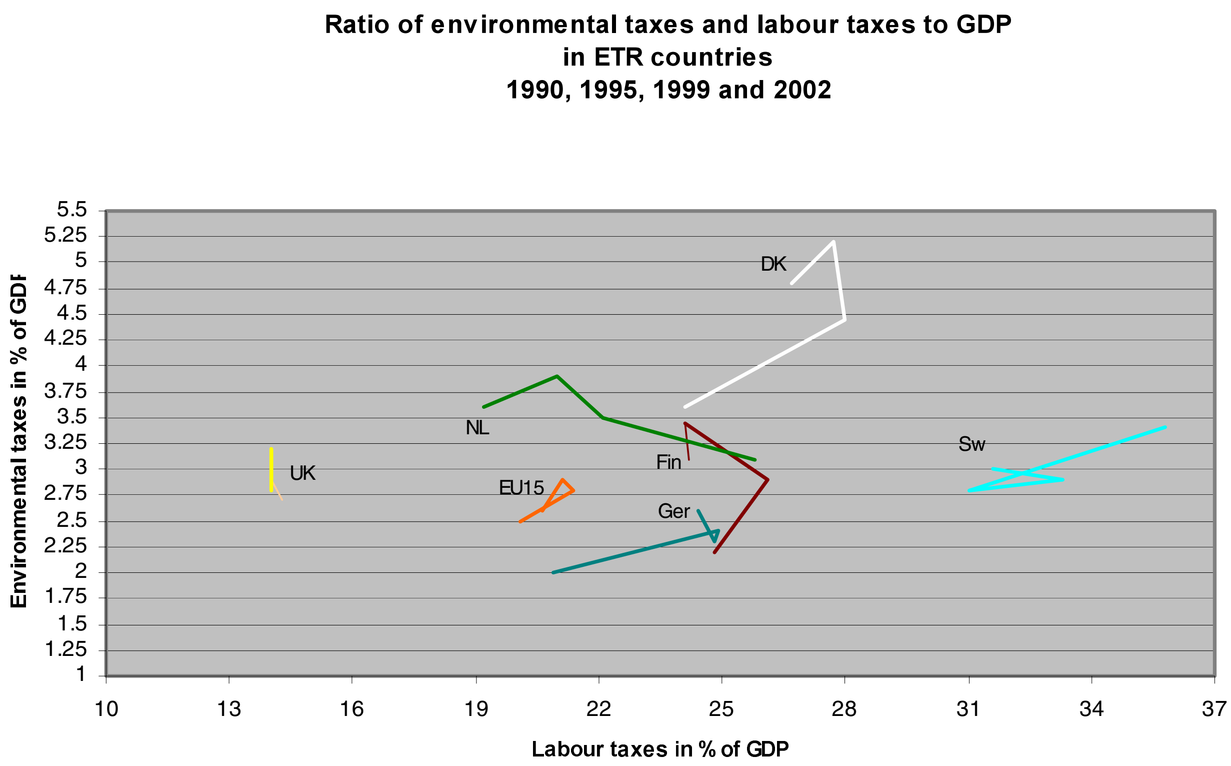
	1990	1995	1999	2002	1990	1995	1999	2002
	Taxes on labour / GDP				Taxes on labour /total taxation			
EU15	20.1	21.4	21.1	20.6	47.8	52.7	50.2	51.0
A	19.3	23.9	24.5	23.4	46.7	56.5	55.3	52.7
B	22.4	25	24.6	25.4	50.6	55.4	53.5	54.5
DK	24.1	28	27.7	26.7	49.4	56.8	53.8	54.6
F	21.9	22.9	23.3	22.8	50.0	52.0	51.0	51.6
Fin	24.8	26.1	24.1	24.2	54.6	56.7	51.5	52.7
Ger	20.9	24.9	24.8	24.4	52.9	61.0	58.6	60.7
Gr	12.1	11.8	13.6	16.8	41.2	36.2	36.5	46.4
Irl	14.6	13.7	11.8	10.2	41.1	41.0	36.8	35.7
It	19.2	18.6	20.5	20.2	49.5	45.1	47.3	48.4
L	16.6	17.7	15.6	16.2	39.7	41.8	38.6	38.7
NL	25.8	22.1	21	19.2	57.1	54.4	50.4	48.6
P	12.6	14	14.4	15.1	38.9	41.7	40.0	41.6
Sp	16.1	16.7	15.9	16.8	54.8	50.0	45.3	46.4
Sw	35.8	31	33.3	31.6	64.2	62.6	61.9	62.5
UK	14.3	14	14	14	37.6	39.5	37.9	39.1
Cz Rep		17.1	16.9	17.8		47.3	48.8	50.2
Cyp		10	9.8	10		37	35	31.7
Est		21	19.8	17.6		55.5	57.4	54.4
Hun		20.8	19.3	19.9		49.9	49.4	51.3
Lat		17.5	16.3	14.9		52	50.5	51.8
Lit		-	-	15		-	-	52.5
Mal		9.7	10	11.7		36	36	35
Pol		-	-	-		-	-	-
Slovakia		-	15.9	14.5		-	46.1	44.9
Slovenia		23.1	21.2	21.8		56.6	53.6	55.3
NewEU10		18.6	17.5	17.5		49.3	48.8	49.8
EU 25		21.4	21	20.6		52.8	50.3	51.1

Note: Data for Poland are not available and data for Lithuania and Slovakia are not complete.
Source: Eurostat 2000, 2004 and 2005

	1990	1995	1999	2002	1990	1995	1999	2002
	Environmental taxation/ GDP				Environmental taxation/ total taxation			
EU15	2.5	2.8	2.9	2.6	6.2	6.9	6.9	6.4
A	1.7	2	2.3	2.6	4.1	4.7	5.2	5.9
B	1.9	2.5	2.6	2.3	4.3	5.5	5.7	4.9
DK	3.6	4.4	5.2	4.8	7.4	8.9	10.1	9.8
F	2.4	2.5	2.4	2	5.5	5.7	5.3	4.5
Fin	2.2	2.9	3.5	3.1	4.8	6.3	7.5	6.8
Ger	2	2.4	2.3	2.6	5.1	5.9	5.4	6.5
Gr	2.2	3.1	3.1	2.6	7.5	9.5	8.3	7.2
Irl	3.7	3.1	3	2.3	10.4	9.3	9.3	8.0
It	3.3	3.7	3.6	2.9	8.5	9.0	8.3	7.0
L	2.2	3.4	3	2.9	5.3	8.0	7.4	6.9
NL	3.1	3.5	3.9	3.6	6.9	8.6	9.4	9.1
P	3.5	3.7	3.6	3.2	10.8	11.0	10.0	8.8
Sp	1.6	2.2	2.4	2.2	5.4	6.6	6.8	6.1
Sw	3.4	2.8	2.9	3	6.1	5.7	5.4	5.9
UK	2.7	2.9	3.2	2.8	7.1	8.2	8.7	7.8
Cz Rep		2.9	2.7	2.6		8	7.7	7.3
Cyp		2.9	2.5	3		10.7	8.8	9.4
Est		0.8	1.7	2		2	5	6.1
Hun		3.1	3.4	2.9		7.4	8.7	7.5
Lat		1.1	2.5	2.3		3.2	7.7	8.1
Lit		-	-	2.2		-	-	6.8
Mal		3	3.9	3.5		11.2	14.1	10.5
Pol		-	-	-		-	-	-
Slova-kia		-	-	-		-	-	-
Slove-nia		0.3	2.2	3.4		0.8	5.6	8.6
NewEU 10		2.5	2.8	2.7		6.5	7.8	7.5
EU 25		2.7	2.8	2.6		6.8	6.8	6.5

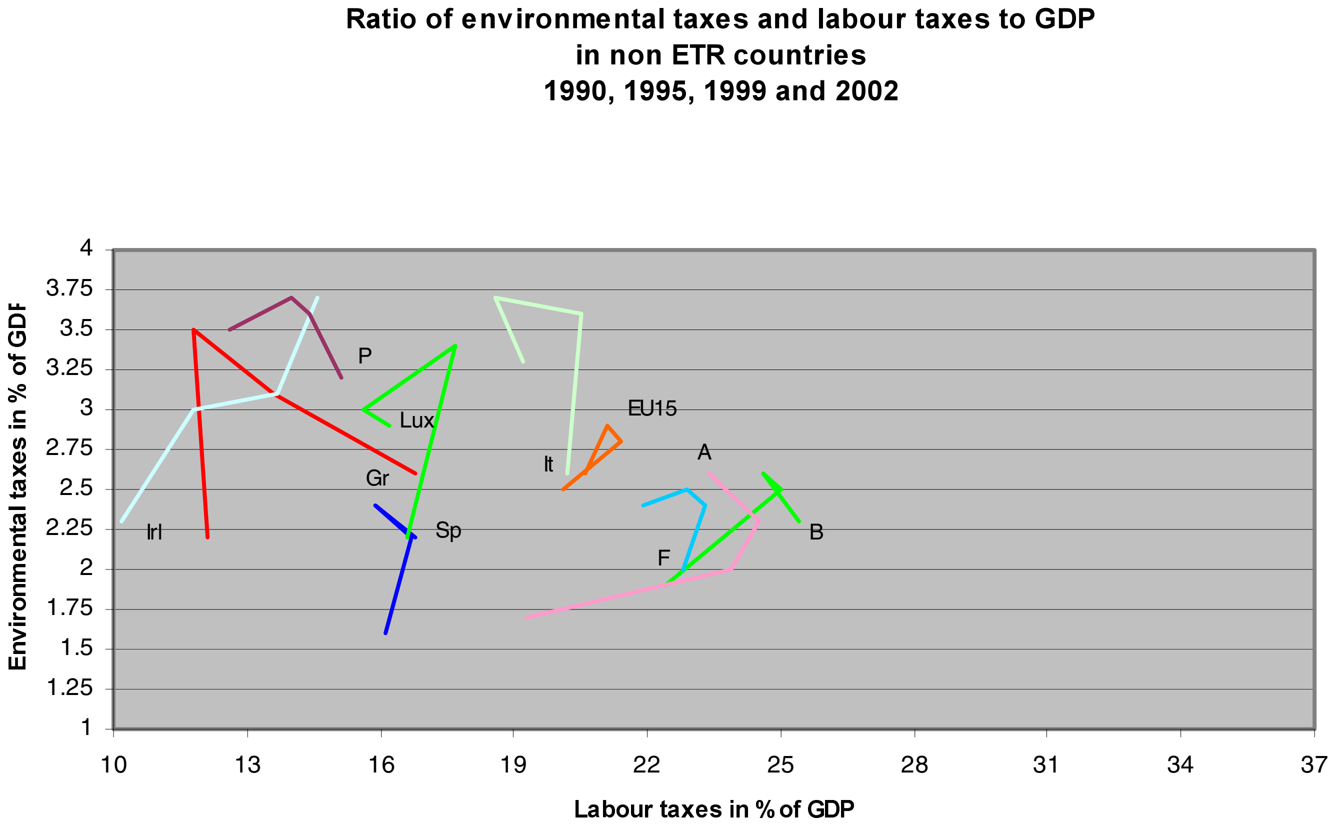
Note: Data for Poland are not available and data for Lithuania and Slovakia are not complete.
Source: Eurostat 2000, 2004 and 2005

Annex 1: Figure 1a: Overview of development of environmental tax-to-GDP ratio and labour taxation-to-GDP ratio in ETR countries[23]

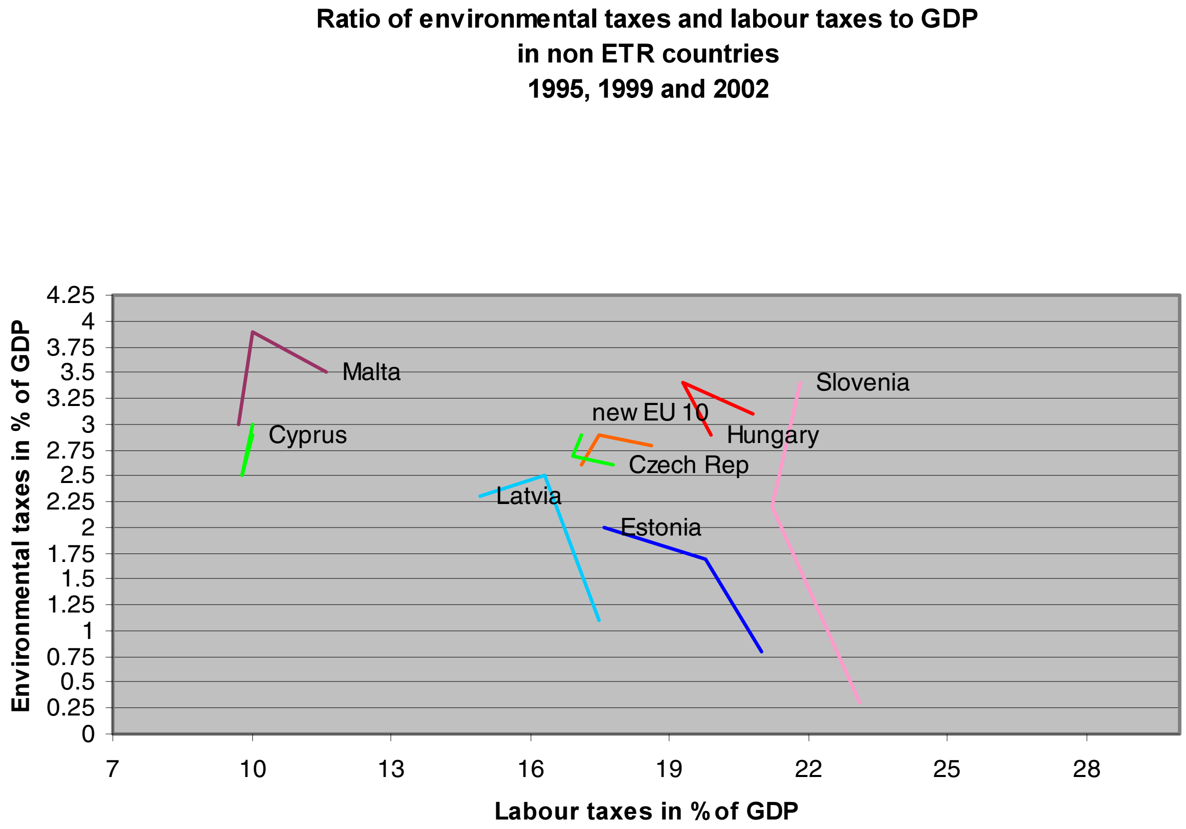


[23] Country abbreviations are set close to the data presenting the situation in 2002. This means that the development in the Netherlands shows signs of an ETR as the share of labour taxes-to-GDP is lower and the share of environmental taxes-to-GDP is higher in 2002 compared to 1990.

Annex 1: Figure 1b: Overview of development of environmental tax-to-GDP ratio and labour taxation-to-GDP ratio in non ETR countries (EU 15)



Annex 1: Figure 1c: Overview of development of environmental tax-to-GDP ratio and labour taxation-to-GDP ratio in the new EU member states



Annex 1: Table 2: Share of environmental taxes to GDP in selected EU member states (in percent)

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Cyprus	2.9	2.8	2.5	2.6	2.5	2.7	3	3	3.8
Czech Republic	2.9	2.7	2.6	2.5	2.7	2.6	2.7	2.6	2.7
Denmark	4.4	4.7	4.7	5.1	5.2	4.7	4.7	4.8	4.7
Estonia	0.8	1.2	1.6	1.7	1.7	1.7	2.1	2	2
Finland	2.9	3.1	3.3	3.3	3.5	3.2	3	3.1	3.2
Germany	2.4	2.3	2.2	2.2	2.3	2.4	2.6	2.6	2.7
Hungary	3.1	3	3	3.5	3.4	3.1	2.9	2.9	2.7
Latvia	1.1	1.6	2.1	3.1	2.5	2.4	2.2	2.3	2.5
Lithuania	-	-	-	-	-	2	2.1	2	2.2
Malta	3	2.7	3.3	3.7	3.9	3.6	3.6	3.5	3.4
Netherlands	3.5	3.7	3.7	3.8	3.9	3.9	3.8	3.6	3.7
Poland	-	-	-	-	-	-	-	-	-
Slovakia	-	-	-	-	-	-	-	-	-
Slovenia	0.3	0.3	0.5	0.9	2.2	3.1	3.4	3.4	3.4
Sweden	2.8	3.2	3	3	2.9	2.8	2.8	2.9	3
United Kingdom	2.9	3	3	3.1	3.2	3.1	2.8	2.7	2.7
EU 25	2.7	2.7	2.7	2.8	2.8	2.7	2.7	2.6	2.7
EU 15	2.7	2.8	2.7	2.8	2.8	2.7	2.7	2.6	2.7
New EU 10	2.5	2.4	2.4	2.6	2.8	2.7	2.8	2.7	2.8

Source: Eurostat 2005

Annex 1: Table 3: Development of implicit tax rate on labour in selected EU member states (in percent)

	1995	1996	1997	1998	1999	2000	2001	2002	2003
Cyprus	22.4	21.5	21.6	22.6	21.9	21.7	23.1	22.4	24.4
Czech Republic	39.4	38.5	38.5	39	38.8	39.7	39.6	39.8	40.1
Denmark	40.9	41.3	41.7	40	41.4	42	41.9	40.1	40
Estonia	38.8	38.7	38.5	39.6	39.2	38.2	37.7	40.1	40.9
Finland	43.9	44.8	43.3	43.8	43.4	44	44.3	43.3	42.1
Germany	39.5	39.7	40.6	40.7	40.4	40.8	40.5	40.4	40.6
Hungary	42.6	43	43.7	42.8	42.7	42.3	41.2	41	39.2
Latvia	39.2	34.6	36.1	37.2	36.9	36.7	36.5	37.5	36.4
Lithuania	-	-	-	-	-	41	40.6	38.8	38.4
Malta	21.8	19.8	22	20.8	22.2	21.5	22.4	22.5	22.4
Poland	-	-	-	-	-	-	-	-	-
Slovakia	-	-	-	-	37.9	34.5	36.2	35.2	32.4
Slovenia	39.2	37.4	37.6	38.1	38.7	38.1	37.9	38.2	38.4
Sweden	46.8	48	48.4	49.4	49	47.9	46.8	45.7	46.1
United Kingdom	25.7	24.7	24.2	25.1	25	25.4	25	24	24.6
EU 25	36	35.9	36.2	36.4	36.4	36.5	36.3	36	35.9
EU 15	36.5	37	37.2	37.3	37.3	37.4	37	36.6	36.8
New EU 10	34.8	33.4	34	34.3	34.8	34.8	35	34.9	34.5

Source: Eurostat 2005

Annex 2

Annex 2: Overview of major tax shifting programmes in EU 15

Country	Tax Shift		Comments and remarks	Size of tax shift and revenue neutrality
	From	To		
Denmark 1993	reduction in tax rates on personal income;	increase in existing taxes on fossil fuels, electricity and waste and new taxes on piped water, wastewater and carrier bags and payroll taxes	the reduction in income taxes were compensated by increase in environmental taxes 12 billion DKK payroll taxes 22 billion DKK and from other measures, such broadening the tax base (11 billion DKK)	Revenue neutral in 1998 – but not in the first years of the reform; Total shift in 1998: 3.9% of GDP and increase in environmental taxes: 1% of GDP
Denmark 1995	reduction in the social security contributions, supplementary pension payments and investment subsidies for energy savings	increase in energy taxes (but industry is reimbursed when entering voluntary agreements) and new tax on SO_2 and natural gas	the major part of revenues generated from the energy taxes were planned for funding investments of energy-savings measures in enterprises, to reduce employers' social security contributions and for support of small and medium sized enterprises	Revenue neutral: 2000 - planned revenues from environmental taxes: 0.2% of GDP
Denmark 1998	reduction in tax rates on personal income for lower and middle incomes	increase in energy taxes (by 15-25 percent) and property tax		No revenue neutrality per annum: See below table
Finland 1997	Personal income (state and local) and employers' social security con-	Energy, CO_2 tax and landfill tax	Reduction of tax revenues of 5.5 billion FIM was planned to be partly financed by revenues from the energy	no revenue neutral reform reduction: 0.9% of GDP

Country	Tax Shift		Comments and remarks	Size of tax shift and revenue neutrality
	From	To		
	tributions		tax (1.1 billion FIM) and from higher landfill tax rates (300 million FIM) in 1997.	increase: 0.2% of GDP
Finland 1998	Labour taxation	Energy and environmental taxes plus corporate profit tax (broadening of tax base)	Planned reduction in revenues generated from labour taxation: 1998 – 1.5 billion FIM 1999 – 3.5 billion FIM	no revenue neutral reform – planned deficit of 1.5 billion FIM in 1998 and 2.5 billion FIM in 1999 reduction 1999: 0.5% of GDP increase 1999: 0.14% of GDP
Germany 1999 – 2003 (a five year programme)	Employers and employees social security contributions	Energy (mineral oils, natural gas and electricity)	A reduction of around 1.7% of employers' and employee's pension contribution in 2003; revenues from energy taxes amounted to 18.6 billion EUR in 2003	Revenue neutrality is part of the programme – 1 bill EUR is earmarked for budget consolidation[24] Revenue 2003: 18.7 billion EUR – 0.9% of GDP
Netherlands 1996, (further increases in the	Personal income, corporate profits, employers' social security contribu-	Energy and CO_2 (regulatory energy tax), water , waste disposal	Revenues were planned to be recycled back (1996) • by cutting employers' social	Revenue neutral reform

[24] A slight discrepancy regarding the usage of ETR revenues can be found in different publications of the German Government. It is mentioned in a report published by the Ministry of Environment in 2004 that around 1 billion EUR is used for budget consolidation. In slight contrast to this statement the Ministry of Finance argues in a press notice in September 2005 that the revenues, which are not hypothecated for reducing pension contributions, are being used for the supporting of renewable energy sources and in addition to compensate the shortfall of tax revenues as a consequence of the financial provision given to the all biogenic fuels. These fuels are exempt from mineral-oil taxes.

Country	Tax Shift		Comments and remarks	Size of tax shift and revenue neutrality
	From	To		
regulatory energy tax in 1999, 2000, and 2001 generating additional 1.5 billion EUR – part of a complete overhaul of the fiscal framework)	tions		security contributions by 0.19%; • by raising the tax credit for self-employed people by 1300 Dfl; • by reducing the corporate income tax by 3% for the first 100,000 Dfl of profits; • by reducing the income tax rate by 0.6%; and • by raising the standard income free allowance by 80 Dfl and the tax free allowance for older people by 100 Dfl. Around 930 million Dfl were planned to be recycled to industry and 1,230 mill Dfl to households.	
Sweden 1991	Personal income tax and social security contributions	Environmental and energy taxes including CO_2 tax and SO_2 tax as well as VAT on energy products	ETR was part of a major fiscal reform – personal income taxes were planned to be cut by 71 billion SEK and environmental taxes were planned to be increased by 18 billion SEK	no revenue neutral reform
Sweden – 10 year programme: 2001-2010	Personal income tax and personal social security contributions	Environmental taxes	A total of 30 billion SKR (3.3 billion EUR) shall be shifted at the end of the ten year programme in 2010 (corresponding to almost 1.4% of GDP) –	no revenue neutral reform: until 2003 (the first three years): 8 billion SEK ad-

Country	Tax Shift		Comments and remarks	Size of tax shift and revenue neutrality
	From	To		
			Green tax shift programme is part of a much bigger reform	ditional generated from environment taxes, eg. around 0.3% of GDP
UK 1996	Employers' national insurance contribution (NIC)	Landfill levy	Revenues are used for a reduction of 0.2% in employers' NIC from 10.2% to 10%	Budget 2004 (forecast) 0.6 billion UKL – 0.05% of GDP
UK 2001	Employers' national insurance contribution (NIC)	Energy/CO_2 emissions under the Climate Change Levy (CCL)	Revenues are used for a reduction of 0.3 % in employers' NICs; revenue is estimated to be around 1 billion UKL pa	Budget 2004 (forecast) 0.8 billion UKL – 0.06% of GDP
UK 2002	Employers' national insurance contribution (NIC)	Aggregates levy (sand, gravel, crushed rock)	Revenues are used for a reduction of 0.1 % in employers' NICs; revenue estimated at ~ 305 million UKL in 2002/3	Budget 2004 (forecast) 0.3 billion UKL – 0.02% of GDP

Source: EEA 2005 (forthcoming) and author's data compilation

Annex 3

Annex 3: Import costs of energy products

	Austria	Belgium	Denmark	Finland	France	Germany	Italy	Spain	Sweden	UK
crude import costs in US Dollar/bbl										
2001	25.32	24.2			24.13	24.15	23.87	23.32	24.03	24.45
2003	29.59	27.72			28.87	28.44	28.58	28.13	28.6	29.13
natural gas pipeline import prices in US Dollar/MBTu										
2001	3.55	3.52		2.58		3.64		3.93		
2003	4.06	3.75		3.21		4.03		4.28		
steam coal import costs in US Dollar/tonne										
2001		47.23	40.67	40.79	42.05	42.03	44.81	37.02		45.46
2003		39.03	50.27	39.99	40.12	39.38	42.45	36.41		43.71

Source: IEA/OECD Energy Prices and Taxes 4th Quarter 2004, Paris, Tables 4, 6, 13

Annex 4

Annex 4: Development of Energy/CO_2 taxes in selected EU member states[25]

Table A4-1: Total energy taxes in Denmark

	petrol unleaded	diesel (transport)	light fuel oil	heavy fuel oil	coal	natural gas	Electricity – other purposes
	DKK/1000l	DKK/1000l	DKK/1000l	DKK/ton	DKK/ton	DKK/1000 m3	DKK/MWh
1988	3330	1760	1760	1980	675		326
1989	3330	1760	1760	1980	765		328.6
1990	2250	1760	1760	1980	765		330
1991	2250	1760	1760	1980	765		330
1992	2250	1760	1760	1980	932		370
1993	2250	1760	1760	1980	932		370
1994	2450	2040	1760	1980	932		400
1995	3020	2270	1760	1980	1012		430
1996	3270	2290	1760	1980	1102	230	460
1997	3320	2390	1760	1980	1192	1450	500
1998	3370	2390	1970	1980	1282	1690	566
1999	3770	2620	1970	2230	1492	1690	581
2000	3870	2850	2000	2270	1542	1820	636
2001	3970	3030	2050	2320	1592	2180	651
2002	4070	3030	2100	2380	1667	2240	666
2003	4070	3030	2100	2380	1667	2240	666
2004	4070	3030	2100	2380	1667	2240	666
2005	4070	3030	2100	2380	1667	2240	666

Note: The Danish SO_2 tax is not considered in the tables.

[25] An attempt was made to present all tax rates valid as of January 1st of the relevant years. However, we depart from this procedure if a major tax revision took place during a specific year meaning that the tax rates shown in the following tables are not the ones which were valid on January 1st. For example, the German eco-tax reform was implemented on April 1st 1999 and therefore we are showing the tax rates valid on April 1st 1999 for the year 1999. In addition, the UK tax rates were calculated as annual average rates.
Data have been compiled by the author and colleagues working at partner institutes of the COMETR project using a whole range of different reports published by institutions such as national statistical offices, international organisations, etc.

Table A4-1a: Energy taxes in Denmark

	petrol unleaded	diesel (transport)	light fuel oil	heavy fuel oil	coal	natural gas	Electricity – other purposes
	DKK/1000l	DKK/1000l	DKK/1000l	DKK/ton	DKK/ton	DKK/1000 m3	DKK/MWh
1988	3330	1760	1760	1980	675		326
1989	3330	1760	1760	1980	765		328.6
1990	2250	1760	1760	1980	765		330
1991	2250	1760	1760	1980	765		330
1992	2250	1760	1760	1980	932		370
1993	2250	1490	1490	1660	690		270
1994	2450	1770	1490	1660	690		300
1995	3020	2000	1490	1660	770		330
1996	3270	2020	1490	1660	860	10	360
1997	3320	2120	1490	1660	950	1230	400
1998	3370	2120	1700	1660	1040	1470	466
1999	3770	2350	1700	1910	1250	1470	481
2000	3870	2580	1730	1950	1300	1600	536
2001	3970	2760	1780	2000	1350	1960	551
2002	4070	2760	1830	2060	1425	2020	566
2003	4070	2760	1830	2060	1425	2020	566
2004	4070	2760	1830	2060	1425	2020	566
2005	3850	2820	1860	2090	1445	2040	576

Table A4-1b: CO_2 taxes in Denmark

	petrol unleaded	diesel (transport)	light fuel oil	heavy fuel oil	Coal	natural gas	Electricity – other purposes
	DKK/1000l	DKK/1000l	DKK/1000l	DKK/ton	DKK/ton	DKK/1000 m3	DKK/MWh
1992							
1993		270	270	320	242		100
1994		270	270	320	242		100
1995		270	270	320	242		100
1996		270	270	320	242	220	100
1997		270	270	320	242	220	100
1998		270	270	320	242	220	100
1999		270	270	320	242	220	100
2000		270	270	320	242	220	100
2001		270	270	320	242	220	100
2002		270	270	320	242	220	100
2003		270	270	320	242	220	100
2004		270	270	320	242	220	100
2005	220	240	240	290	222	200	90

Note: CO_2 tax data are only presented in 1993 although the CO_2 tax rate was already introduced in May 1992.

Table A4-1c: Effective CO_2 tax rate for businesses

	Light process		Heavy process	
	CO_2 tax rate		CO_2 tax rate	
	with agreement	w/out agreement	with agreement	w/out agreement
	DKK/ton CO_2	DKK/ton CO_2	DKK/ton CO_2	DKK/ton CO_2
1992				
1993		50		5
1994		50		5
1995		50		5
1996	50	50	3	5
1997	50	60	3	10
1998	50	70	3	15
1999	58	80	3	20
2000	68	90	3	25
2001	68	90	3	25
2002	68	90	3	25
2003	68	90	3	25
2004	68	90	3	25
2005	68	90	3	25

Note: The nominal CO_2 tax rate was reduced to 90 DKK/ton CO_2 from 100 DKK/ton CO_2 in 2005. However, this reduction was not passed on to businesses, i.e. the effective tax rates have been kept constant in 2005 meaning that the share has been increased businesses have to pay.

Table A4-2: Energy taxes in Finland

	petrol unleaded	diesel (trans-port)	light fuel oil	heavy fuel oil	coal	natural gas	households electricity	industry electricity
	EUR/1000l	EUR/1000l	EUR/1000l	EUR/ton	EUR/ton	EUR/m3	EUR/MWh	EUR/MWh
1988	146	124	0	0	0	0		
1989	160	142	0	0	0	0.002		
1990	260	127.5	3.4	3.4	2.7	0.002		
1991	316	134.5	3.5	3.5	2.8	0.002		
1992	359	134.5	3.5	3.5	2.8	0.002		
1993	479	150.5	14.1	11.2	5.6	0.004		
1994	401	198	20.5	19.8	11.3	0.011		
1995	452	300	30.2	31.2	19.5	0.009		
1996	519	300	30.2	31.2	19.5	0.009		
1997	519	300	48.8	37.2	28.4	0.012	5.6	2.4
1998	552	326	52.0	44.0	33.4	0.014	5.6	3.4
1999	552	325	63.7	54.0	41.4	0.017	6.9	4.2
2000	552	325	63.7	54.0	41.4	0.017	6.9	4.2
2001	552	325	63.7	54.0	41.4	0.017	6.9	4.2
2002	552	325	63.7	54.0	41.4	0.017	6.9	4.2
2003	581.3	343	67.1	56.8	43.5	0.018	7.2	4.4
2004	581.3	343	67.1	56.8	43.5	0.018	7.2	4.4
2005	581.3	343	67.1	56.8	43.5	0.018	7.2	4.4

Notes: - strategic stockpile fee and oil pollution levy levied on all energy products are not reported. Electricity tax scheme changed in 1997 – until 1997 Finland adopted an input tax scheme, i.e. energy products used for electricity generation were subject to energy taxation

Table A4-3: Energy tax rates in Germany

							industry	households
	petrol unleaded	diesel (trans-port)	gas oil	heavy fuel oil	coal	natural gas – used for heating	electrivity - effective	electrivity
	EUR/kl	EUR/kl	EUR/kl	EUR/ton	EUR/ton	EUR/MWh	EUR/kWh	EUR/kWh
1988	240	230	8.2	7.2	0	0.0	0.005	0.007
1989	291	230	28.1	14.5	0	1.3	0.006	0.009
1990	291	230	28.4	14.6	0	1.3	0.005	0.009
1991	307	230	39.0	14.6	0	1.8	0.005	0.009
1992	419	280	39.6	14.9	0	1.8	0.005	0.008
1993	419	280	41.2	15.5	0	1.9	0.005	0.009
1994	501	317	41.7	15.6	0	1.9	0.006	0.010
1995	501	317	42.7	16.0	0	1.9	0.006	0.011
1996	501	317	41.9	15.7	0	1.9	0	0
1997	501	317	40.7	15.3	0	1.8	0	0
1998	501	317	40.9	15.2	0	1.8	0	0
1999	532	348	61.4	15.3	0	3.5	0.00205	0.01023
2000	562	378	61.4	15.3	0	3.5	0.00256	0.01278
2001	593	409	61.4	17.9	0	3.5	0.00307	0.01534
2002	624	440	61.4	17.9	0	3.5	0.00704	0.0179
2003	655	471	61.4	25	0	5.5	0.0123	0.0205
2004	655	471	61.4	25	0	5.5	0.0123	0.0205
2005	655	471	61.4	25	0	5.5	0.0123	0.0205

Table A4-3a: The effects of the German ETR on energy tax rates

		1999	April 1999	January 2000	January 2001	January 2002	January 2003	January 2004
Tax Rates								
Petrol unleaded	EUR/1000 litres	501.1	531.7	562.4	593.1	623.8	654.5	654.5
Diesel	EUR/1000 litres	317.0	347.7	378.4	409.0	439.7	470.4	470.4
Natural gas	EUR/MWh	24.3	25.8	27.3	28.8	30.3	31.8	31.8
Natural gas (heating)	EUR/MWh	1.8	3.5	3.5	3.5	3.5	5.5	5.5
LPG	EUR/ 1000 kg	952.5	1005.5	1058.4	1111.2	1164.1	1217.0	1217.0
LPG (heating)	EUR/1000 kg	25.6	38.4	38.4	38.4	38.4	60.6	60.6
Light Fuel Oil (LFO)	EUR/1000 litres	40.9	61.4	61.4	61.4	61.4	61.4	61.4
reduced LFO	EUR/1000 litres	18.4	34.8	34.8	34.8	34.8	34.8	34.8
Heavy fuel oil (HFO) - generation of heat	EUR/1000 kg	15.3	15.3	17.9	17.9	17.9	25.0	25.0
HFO - generation of electricity	EUR/1000 kg	28.1	28.1	17.9	17.9	17.9	25.0	25.0
Electricity	EUR/MWh	0.0	10.2	12.8	15.3	17.9	20.5	20.5
Electicity - night storage heating	EUR/MWh	0.0	5.1	6.4	7.7	9.0	12.3	12.3
Electricity - manufacturing industry, agriculture	EUR/MWh	0.0	2.1	2.6	3.1	3.6	12.3	12.3
Increase in tax rates p.a.								
Petrol unleaded	EUR/1000 litres		30.7	30.7	30.7	30.7	30.7	
Diesel	EUR/1000 litres		30.7	30.7	30.6	30.7	30.7	
Natural gas	EUR/MWh		1.5	1.5	1.5	1.5	2.9	
Natural gas (heating)	EUR/MWh		1.7	1.7	1.7	1.7	2	
LPG	EUR/1000 kg		53.0	52.9	52.9	52.9	52.9	
LPG (heating)	EUR/1000 kg		12.8	12.8	12.8	12.8	22.2	
LFO	EUR/1000 litres		20.5	0.0	0.0	0.0	0.0	
reduced LFO	EUR/1000 litres		16.4	0.0	0.0	0.0	0.0	
HFO - generation of heat	EUR/1000 kg		0.0	2.6	0.0	0.0	7.1	
HFO - generation of electricity	EUR/1000 kg		0.0	-10.2	0.0	0.0	7.1	
Electricity	EUR/MWh		10.2	2.6	2.6	2.6	2.6	
Electicity - night storage heating	EUR/MWh		5.1	1.3	1.3	1.3	3.3	
Electricity - manufacturing industry, agriculture	EUR/MWh		2.1	0.5	0.5	4.0	5.3	

Table A4-3b: Development of energy taxes introduced as part of the ETR

	petrol unleaded	diesel (transport)	gas oil	heavy fuel oil	natural gas	electricity
	EUR/kl	EUR/kl	EUR/kl	EUR/ton	EUR/MWh	EUR/kWh
1999	30.7	30.7	20.5	0	1.7	0.01023
2000	61.4	61.4	20.5	2.6	1.7	0.01278
2001	92.1	92.1	20.5	2.6	1.7	0.01534
2002	122.8	122.8	20.5	2.6	1.7	0.0179
2003	153.5	153.5	20.5	7.1	3.7	0.0205
2004	153.5	153.5	20.5	7.1	3.7	0.0205
2005	153.5	153.5	20.5	7.1	3.7	0.0205

Table A4-3c: Effective tax rates for manufacturing industry, agriculture, forestry and fishery

	gas oil	natural gas	electricity
	EUR/kl	EUR/MWh	EUR/kWh
1999	45.0	2.2	0.002046
2000	45.0	2.2	0.002556
2001	45.0	2.2	0.003068
2002	45.0	2.2	0.00358
2003	53.2	4.0	0.0123
2004	53.2	4.0	0.0123
2005	53.2	4.0	0.0123

Note: the tax rates presented are taking into account already existing energy taxes (i.e. in place before 1999) and the energy taxes levied under the ETR. Additional tax regulation known under the term '*Spitzenausgleich'* are not considered.

Table A4-4: Development of tax rates in the Netherlands

	petrol unleaded	diesel (transport)	gas oil	light fuel oil	heavy fuel oil	coal
	EUR/1000l	EUR/1000l	EUR/1000l	EUR/1000l	EUR/ton	EUR/ton
1988	338.6	123.6		52.4	16.8	2.5
1989	337.6	122.2		50.8	17.1	2.5
1990	348.9	174.0		52.9	20.3	5.5
1991	394.4	193.9		53.6	22.5	9.1
1992	443.2	212.3		62.0	29.2	10.9
1993	461.9	272.0		65.0	29.9	10.4
1994	518.1	312.5		66.1	30.2	10.5
1995	527.23	315.83	62.08	61.98	31.72	11.14
1996	528.29	316.35	74.17	73.98	31.11	10.93
1997	514.70	310.29	71.78	71.60	30.11	10.58
1998	565.81	331.58	97.36	96.82	29.99	10.53
1999	581.85	341.01	117.43	116.84	30.52	10.83
2000	591.76	346.81	139.29	138.61	30.77	11.02
2001	602.41	353.03	187.40	186.24	31.04	11.22
2002	621.08	353.26	191.82	196.89	31.53	11.99
2003	643.44	351.34	198.1	196.99	32.11	11.99
2004	658.88	365.77	206.5	205.23	32.51	12.28
2005	668.10	364.91	207.61	206.28	32.51	12.45

Note: Strategic stockpile fee is not included in the tax rates

Table A4-4a: Tax levied on natural gas

Annual consumption between	0-800	801-5,000	5,001-170,000	170,001-1 mill	1 mill - 10 mill	>10 mill - non-business use	>10 mill – business use
	EUR/m3	EUR/m3	EUR/m3	EUR/m3	EUR/m3	EUR/m3	EUR/m3
1988	0.0003	0.0003	0.0003				
1989	0.0003	0.0003	0.0003				
1990	0.0020	0.0020	0.0020				
1991	0.0042	0.0042	0.0042				
1992	0.0111	0.0111	0.0111				
1993	0.0095	0.0095	0.0095				
1994	0.0096	0.0096	0.0096				
1995	0.0103	0.0103	0.0103	0.0103	0.0103	0.0067	0.0067
1996	0.0101	0.0250	0.0250	0.0101	0.0101	0.0065	0.0065
1997	0.0097	0.0387	0.0387	0.0097	0.0097	0.0063	0.0063
1998	0.0097	0.0526	0.0526	0.0097	0.0097	0.0063	0.0063
1999	0.0100	0.0825	0.0825	0.0825	0.0100	0.0065	0.0065
2000	0.0102	0.1046	0.0621	0.0172	0.0102	0.0066	0.0066
2001	0.1306	0.1306	0.0665	0.0208	0.0103	0.0068	0.0068
2002	0.1350	0.1350	0.0689	0.0217	0.0110	0.0070	0.0070
2003	0.1395	0.1395	0.0710	0.0221	0.0110	0.0073	0.0073
2004	0.1429	0.1429	0.0727	0.0113	0.0113	0.0106	0.0075
2005	0.1494	0.1494	0.1019	0.0311	0.0115	0.0107	0.0076

Table A4-4b: Tax levied on electricity

Annual consumption between	0-800	800-10,000	10,000 - 50,000	50,000-10 mill.	>10 mill - non business use	>10 mill – business use
	EUR/kWh	EUR/kWh	EUR/kWh	EUR/kWh	EUR/kWh	EUR/kWh
1996	0	0.0138	0.0138	0	0	0
1997	0	0.0133	0.0133	0	0	0
1998	0	0.0133	0.0133	0.000	0	0
1999	0	0.0225	0.0147	0.001	0	0
2000	0	0.0372	0.0161	0.002	0	0
2001	0.0583	0.0583	0.0194	0.0059	0	0
2002	0.0601	0.0601	0.02	0.0061	0	0
2003	0.0639	0.0639	0.0207	0.0063	0	0
2004	0.0654	0.0654	0.0065	0.0065	0.001	0.0005
2005	0.0699	0.0699	0.0263	0.0086	0.001	0.0005

Table A4-5: Overview of energy tax development in Slovenia

	Petrol unleaded	diesel (transport)	light fuel oil	heavy fuel oil	natural gas	coal	electricity
	SIT/1000 l	SIT/1000 l	SIT/1000 l	SIT/ton	SIT/1000 m3	SIT/ton	SIT/MWh
1990	140%	90%	20%	32%	5%	5%	5%
1991	140%	90%	20%	32%	5%	5%	5%
1992	140%	90%	20%	32%	5%	5%	5%
1993	140%	90%	20%	32%	5%	5%	5%
1994	140%	90%	20%	32%	5%	5%	5%
1995	140%	90%	20%	32%	5%	5%	5%
1996	140%	90%	20%	32%	5%	5%	5%
1997	140% 2,200	90% 2,600	0 2,600 (2,600)	0 3,100 (3,100)	0 1,300 (1,300)	0 2,500 (2,500)	0
1998	140% 6,600	90% 7,800	0 7,800 (7,800)	0 9,300 (9,300)	0 3,900 (3,900)	0 7,500 (7,500)	0
1999	76,260 6,600 (82,860)	59,950 7,800 (67,750)	5,006 7,800 (12,806)	0 9,300 (9,300)	1,800 3,900 (5,700)	0 7,500 (7,500)	0
2000	76,260 6,600 (82,860)	59,950 7,800 (67,750)	5,006 7,800 (12,806)	0 9,300 (9,300)	1,800 3,900 (5,700)	0 7,500 (7,500)	0
2001	76,260 6,600 (82,860)	59,950 7,800 (67,750)	7,506 7,800 (15,306)	0 9,300 (9,300)	3,300 3,900 (7,200)	0 7,500 (7,500)	0
2002	76,260 6,600 (82,860)	59,950 7,800 (67,750)	7,506 7,800 (15,306)	0 9,300 (9,300)	3,300 3,900 (7,200)	0 7,500 (7,500)	0
2003	76,260 6,600 (82,860)	59,950 7,800 (67,750)	9,266 7,800 (17,066)	380 9,300 (9,680)	3,300 3,900 (7,200)	0 7,500 (7,500)	0
2004	78,607 6,600 (85,207)	64,476 7,800 (72,276)	28,338 7,800 (36,138)	2,100 9,300 (11,400)	3,300 3,900 (7,200)	0 7,500 (7,500)	0
2005	90,908 6,600 (97,508)	73,970 7,800 (81,700)	33,085 7,800 (40,882)	2,100 9,300 (11,400)	3,300 3,900 (7,200)	0 7,500 (7,500)	0

Note: first figure shows excise tax, the second figure in each cell starting in the year 1997 shows the CO_2 tax and the figures in brackets show total tax levied on energy products; coal – hard coal

Table A4-6: Overview of tax development in Sweden

	petrol unleaded	diesel (transport)	light fuel oil	heavy fuel oil	coal	natural gas	household electricity	industry electricity
	SEK/1000l	SEK/1000l	SEK/1000l	SEK/ton	SEK/ton	SEK/1000m3	SEK/MWh	SEK/MWh
1988	2330	660	778	778	305	308	72	50
1989	2580	860	978	978	450	308	72	50
1990	2920	960	1078	1078	460	350	72	50
1991	2980	910	1260	1260	850	710	72	50
1992	2950	810	1260	1260	850	710	72	50
1993	3880	1010	1460	1460	1030	855	85	0
1994	3910	2260	1519	1519	1071	889	88	0
1995	4010	2424	1559	1559	1099	912	90	0
1996	4160	2530	1644	1644	1167	979	97	0
1997	4270	2574	1704	1704	1191	997	113	0
1998	4470	2672	1801	1801	1236	1033	152	0
1999	4430	2649	1785	1785	1225	1024	151	0
2000	4470	2922	1801	1801	1236	1033	162	0
2001	4500	3039	2215	2215	1622	1367	181	0
2002	4620	3121	2505	2505	1865	1575	198	0
2003	4710	3178	2894	2894	2199	1861	227	0
2004	4790	3331	3330	3330	2572	2183	241	5
2005	4960	3645	3344	3344	2583	2192	254	5

Note: NO_X charge and SO_2 tax are not considered.

Table A4-6a: Nominal vs. effective tax rates for the manufacturing industry

	nominal tax rate				effective tax rate – manufacturing industry			
	light fuel oil	heavy fuel oil	coal	natural gas	light fuel oil	heavy fuel oil	coal	natural gas
	SEK/1000l	SEK/ton	SEK/ton	SEK/1000m3	SEK/1000l	SEK/ton	SEK/ton	SEK/1000m3
1990	1078	1078	460	350	1078	1078	460	350
1991	1260	1260	850	710	1260	1260	850	710
1992	1260	1260	850	710	1260	1260	850	710
1993	1460	1460	1030	855	230	230	200	170
1994	1519	1519	1071	889	239	239	208	177
1995	1559	1559	1099	912	246	246	214	181
1996	1644	1644	1167	979	264	264	229	197
1997	1704	1704	1191	997	263	263	229	197
1998	1801	1801	1236	1033	529	529	460	396
1999	1785	1785	1225	1024	525	525	456	393
2000	1801	1801	1236	1033	529	529	460	396
2001	2215	2215	1622	1367	535	535	466	401
2002	2505	2505	1865	1575	539	539	469	404
2003	2894	2894	2199	1861	544	544	473	407
2004	3330	3330	2572	2183	546	546	475	409
2005	3344	3344	2583	2192	548	548	477	410

Table A4-7: The UK energy tax rates on mineral oil products

	petrol unleaded	diesel (transport)	gas oil	fuel oil	heavy fuel oil	electricity – fossil fuel levy
	UKL/litre	UKL/litre	UKL/litre	UKL/litre	UKL/litre	*ad valorem tax (in %)*
1988	0.1842	0.1729	0.011	0.0077	0.00778	
1989	0.1772	0.1729	0.011	0.0077	0.00778	
1990	0.192	0.207	0.012	0.008	0.00823	8.8
1991	0.219	0.219	0.013	0.009	0.00897	9.1
1992	0.233	0.227	0.013	0.009	0.00953	9.1
1993	0.256	0.248	0.015	0.010	0.0105	8.3
1994	0.285	0.279	0.017	0.012	0.016	8.3
1995	0.316	0.316	0.022	0.017	0.0166	8.3
1996	0.345	0.345	0.023	0.018	0.0181	3.1
1997	0.385	0.386	0.025	0.020	0.0194	1.9
1998	0.431	0.438	0.028	0.021	0.02	0.8
1999	0.467	0.493	0.030	0.026	0.0218	0.2
2000	0.486	0.516	0.031	0.027	0.0265	0.3
2001	0.480	0.518	0.031	0.027	0.0274	0.4
2002	0.488	0.518	0.031	0.027	0.0274	0.0
2003	0.492	0.522	0.039	0.036	0.0274	0.0
2004	0.502	0.533	0.043	0.039	0.0382	0.0
2005	0.506	0.537	0.056	0.052	0.0482	0.0

Table A4-7a: The Climate Change Levy (only levied on energy consumption by business)

	only business use			
	natural gas	electricity	coal	lpg
	UKL/kWh	UKL/kWh	UKL/kWh	UKL/kWh
2001	0.0015	0.0043	0.0015	0.0007
2002	0.0015	0.0043	0.0015	0.0007
2003	0.0015	0.0043	0.0015	0.0007
2004	0.0015	0.0043	0.0015	0.0007
2005	0.0015	0.0043	0.0015	0.0007

Annex 5

Annex 5: Overview of effective tax rates in selected EU member states[26]

Table A5-1: Overview of tax rates on light fuel oil – nominal versus effective rates (industry): in EUR/1000litres

	Nominal tax rates							Effective tax rates								
								space heating	light process – with agreement	heavy process – with agreement						
	Dk	Fin	Ger	NL	Slov	Sw	UK	Dk	Dk	Dk	Fin	Ger	NL	NL	Sw	UK
1988	221.4		8.2	52.4		107.5	11.7					8.2	52.4	52.4	107	11.7
1989	218.6		28.1	50.8		137.7	11.5					28.1	50.8	50.8	138	11.5
1990	223.9	3.4	28.4	52.9	20%	143.4	11.5				3.4	28.4	52.9	52.9	143.4	11.5
1991	222.5	3.5	39.0	53.6	20%	168.4	12.7				3.5	39.0	53.6	53.6	168.4	12.7
1992	225.4	3.5	39.6	62.0	20%	167.3	12.7				3.5	39.6	62.0	62.0	167.3	12.7
1993	231.9	14.1	41.2	65.0	20%	160.1	13.3				14.1	41.2	65.0	65.0	25.2	13.3
1994	233.4	20.5	41.7	66.1	20%	165.8	15.4				20.5	41.7	66.1	66.1	26.1	15.4
1995	240.2	30.2	42.7	62.0	20%	167.1	20.2				30.2	42.7	62.0	62.0	26.3	20.2
1996	239.2	30.2	41.9	74.0	20%	193.1	22.4		18.3	1.1	30.2	41.9	74.0	60.8	31.0	22.4
1997	235.2	48.8	40.7	71.6	14.4	197.0	28.5		18.0	1.1	48.8	40.7	71.6	59.2	30.4	28.5
1998	262.7	52.0	40.9	96.8	41.9	202.0	31.6	262.7	18.0	1.1	52.0	40.9	96.8	58.7	59.3	31.6
1999	264.9	63.7	61.4	116.8	66.1	202.7	39.0	264.9	21.1	1.1	63.7	45.0	116.8	59.3	59.6	39.0
2000	268.3	63.7	61.4	138.6	62.5	213.3	44.6	268.3	24.6	1.1	63.7	45.0	138.6	59.5	62.6	44.6
2001	275.1	63.7	61.4	186.2	70.5	239.3	44.1	275.1	24.6	1.1	63.7	45.0	186.2	59.7	57.8	44.1
2002	282.6	63.7	61.4	196.9	67.7	273.4	43.6	282.6	24.7	1.1	63.7	45.0	196.9	60.2	58.9	43.6
2003	282.6	67.1	61.4	197.0	73.0	317.2	51.3	282.6	24.7	1.1	67.1	53.2	197.0	60.7	59.6	51.3
2004	282.3	67.1	61.4	205.2	153.5	365.0	57.5	282.3	24.7	1.1	67.1	53.2	205.2	61.0	59.8	57.5
2005	282.3	67.1	61.4	206.3	170.3	366.5	77.0	282.3	24.7	1.1	67.1	53.2	206.3	61.6	59.8	77.0

Note: effective tax rates: special tax provisions are considered where applicable! NL – second row is valid for consumption of light fuel exceeding the taxable event (ceiling is 159,000 litres per annum)

[26] The following tables compare the development of nominal tax rates and the taxes levied on industry taking into account special tax provisions, such as tax exemptions. Special refund schemes, such as the ones implemented for example in Finland and Sweden, are not considered. These tables can only be seen as indicative as the reality may look different.

Table A5-2: Overview of tax rates on heavy fuel oil – nominal versus effective rates (industry) in EUR/ton

	Nominal tax rates							Effective tax rates – industry							
								space heating	light process – with agree-ment	heavy process – with agree-ment					
	Dk	Fin	Ger	NL	Slov	Sw	UK	Dk	Dk	Dk	Fin	Ger	NL	Sw	UK
1988	249.1	0	7.2	16.8		107.5	11.9				0	7.2	16.8	107	11.9
1989	246.0	0	14.5	17.1		137.7	11.7				0	14.5	17.1	138	11.7
1990	251.9	3.4	14.6	20.3	32%	143.4	11.7				3.4	14.6	20.3	143.4	11.7
1991	250.3	3.5	14.6	22.5	32%	168.4	13.0				3.5	14.6	22.5	168.4	13.0
1992	253.5	3.5	14.9	29.2	32%	167.3	13.0				3.5	14.9	29.2	167.3	13.0
1993	260.9	11.2	15.5	29.9	32%	160.1	13.6				11.2	15.5	29.9	25.2	13.6
1994	262.6	19.8	15.6	30.2	32%	165.8	20.7				19.8	15.6	30.2	26.1	20.7
1995	270.2	31.2	16.0	31.7	32%	167.1	20.2				31.2	16.0	31.7	26.3	20.2
1996	269.0	31.2	15.7	31.1	32%	193.1	22.5		21.7	1.3	31.2	15.7	31.1	31.0	22.5
1997	264.6	37.2	15.3	30.1	17.2	197.0	28.3		21.4	1.3	37.2	15.3	30.1	30.4	28.3
1998	264.0	44.0	15.2	30.0	49.9	202.0	29.9	264.0	21.3	1.3	44.0	15.2	30.0	59.3	29.9
1999	299.9	54.0	15.3	30.5	48.0	202.7	33.5	299.9	25.0	1.3	54.0	15.2	30.5	59.6	33.5
2000	304.5	54.0	15.3	30.8	45.4	213.3	44.0	304.5	29.2	1.3	54.0	15.8	30.8	62.6	44.0
2001	311.3	54.0	17.9	31.0	42.8	239.3	44.5	311.3	29.2	1.3	54.0	15.8	31.0	57.8	44.5
2002	320.3	54.0	17.9	31.5	41.1	273.4	44.1	320.3	29.3	1.3	54.0	15.8	31.5	58.9	44.1
2003	320.3	56.8	25.0	32.1	41.4	317.2	40.0	320.3	29.3	1.3	56.8	19.5	32.1	59.6	40.0
2004	319.9	56.8	25.0	32.5	48.4	365.0	56.9	319.9	29.2	1.3	56.8	19.5	32.5	59.8	56.9
2005	319.9	56.8	25.0	32.5	47.5	366.5	71.8	319.9	29.2	1.3	56.8	19.5	32.5	59.8	71.8

Note: effective tax rates: special tax provisions are considered where applicable!

Table A5-3: Overview of tax rates on coal – nominal versus effective rates (industry) in EUR/ton

	Nominal tax rates							Effective tax rates – industry								
								space heating	light process – with agree-ment	heavy process – with agree-ment						
	Dk	Fin	Ger	NL	Slov	Sw	UK - CCL	Dk	Dk	Dk	Fin	Ger	NL	Slov	Sw	UK – CCL (80%)
1988	84.9		0	2.5		42.1	0				0	0	2.5		42	0
1989	95.0		0	2.5		63.4	0				0	0	2.5		63	0
1990	97.3	2.7	0	5.5	5%	61.2	0				2.7	0	5.5		61.2	0
1991	96.7	2.8	0	9.1	5%	113.6	0				2.8	0	9.1		113.6	0
1992	119.3	2.8	0	10.9	5%	112.9	0				2.8	0	10.9		112.9	0
1993	122.8	5.6	0	10.4	5%	112.9	0				5.6	0	10.4		21.9	0
1994	123.6	11.3	0	10.5	5%	116.9	0				11.3	0	10.5		22.7	0
1995	138.1	19.5	0	11.1	5%	117.8	0				19.5	0	11.1		22.9	0
1996	149.7	19.5	0	10.9	5%	137.1	0		16.4	1.0	19.5	0	10.9		26.9	0
1997	159.3	28.4	0	10.6	13.9	137.7	0		16.2	1.0	28.4	0	10.6		26.4	0
1998	170.9	33.4	0	10.5	40.3	138.6	0	170.9	16.1	1.0	33.4	0	10.5		51.6	0
1999	200.7	41.4	0	10.8	38.7	139.1	0	200.7	18.9	1.0	41.4	0	10.8		51.8	0
2000	206.9	41.4	0	11.0	36.6	146.4	0	206.9	22.1	1.0	41.4	0	11.0		54.5	0
2001	213.6	41.4	0	11.2	34.5	175.3	19.5	213.6	22.1	1.0	41.4	0	11.2		50.3	3.9
2002	224.3	41.4	0	12.0	33.2	203.6	19.3	224.3	22.1	1.0	41.4	0	12.0		51.2	3.9
2003	224.3	43.5	0	12.0	32.1	241.0	17.5	224.3	22.1	1.0	43.5	0	12.0		51.8	3.5
2004	224.1	43.5	0	12.3	31.9	281.9	17.9	224.1	22.1	1.0	43.5	0	12.3		52.0	3.6
2005	224.1	43.5	0	12.5	31.3	283.1	17.9	224.1	22.1	1.0	43.5	0	12.5		52.1	3.6

Note: effective tax rates: special tax provisions are considered where applicable! UK – CCL: 80 percent reduction for energy-intensive industries

Table A5-4: Overview of tax rates on natural gas – nominal versus effective rates (industry) in EUR/1000 m3

	Nominal tax rates							Effective tax rates – industry							
				Con-sump-tion 5,001 – 170,000				space heating	light process – with agreement	heavy process- with agree-ment			Consu mprion 1 mill-10 mill		
	Dk	Fin	Ger	NL	Slov	Sw	UK - CCL	Dk	Dk	Dk	Fin	Ger	NL	Sw	UK – CCL (80%)
1988	0	0	0	0		42.5	0				0.0	0	0	42.5	0
1989	0	2.0	13.6	0		43.4	0				2.0	13.6	0	43.4	0
1990	0	2.0	13.7	0	5%	46.5	0				2.0	13.7	0	46.5	0
1991	0	2.0	19.0	0	5%	94.9	0				2.0	19.0	0	94.9	0
1992	0	2.0	19.3	0	5%	94.3	0				2.0	19.3	0	94.3	0
1993	0	4.0	20.1	0	5%	93.8	0				4.0	20.1	0	18.6	0
1994	0	11.0	20.3	0	5%	97.1	0				11.0	20.3	0	19.3	0
1995	0	9.0	20.8	10.3	5%	97.7	0				9.0	20.8	10.3	19.4	0
1996	31	9.0	20.4	25.0	5%	115.0	0		14.9	0.9	9.0	20.4	10.1	23.2	0
1997	194	12.0	19.9	38.7	7.2	115.2	0		14.7	0.9	12.0	19.9	9.7	22.7	0
1998	225	14.0	19.8	52.6	20.9	115.9	0	225.4	14.7	0.9	14.0	19.8	9.7	44.4	0
1999	227	17.0	37.7	82.5	29.4	116.3	0	227.3	17.2	0.9	17.0	23.5	10.0	44.6	0
2000	244	17.0	37.7	62.1	27.8	122.3	0	244.2	20.1	0.9	17.0	23.5	10.2	46.9	0
2001	293	17.0	37.7	66.5	33.2	147.7	26.1	292.5	20.1	0.9	17.0	23.5	10.3	43.3	5.2
2002	301	17.0	37.7	68.9	31.8	171.9	25.8	301.5	20.1	0.9	17.0	23.5	11.0	44.1	5.2
2003	301	18.0	59.6	71.0	30.8	204.0	23.5	301.5	20.1	0.9	18.0	43.9	11.0	44.6	4.7
2004	301	18.0	59.6	72.7	30.6	239.3	23.9	301.1	20.1	0.9	18.0	43.9	11.3	44.8	4.8
2005	301	18.0	59.6	101.9	30.0	240.2	23.9	301.1	20.1	0.9	18.0	43.9	11.5	44.8	4.8

Note: effective tax rates: special tax provisions are considered where applicable! ! UK – CCL 80 percent reduction for energy-intensive industries

Table A5-5: Overview of tax rates on electricity– nominal versus effective rates (industry) in EUR/MWh

	Nominal tax rates							Effective tax rates – industry					
				Consumption: 800-10,000							Consumption: 50,000 - 10 mill.	industry	
	Denmark	Finland	Germany	Netherlands	Slovenia	Sweden	UK – CCL	Denmark	Finland	Germany	Netherlands	Sweden	UK – CCL (80%)
	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh	EUR/MWh
1988	41.0	0	7.4			9.9	0		0	4.8		6.9	0
1989	40.8	0	8.8			10.1	0		0	5.6		7.0	0
1990	42.0	0	8.6		5%	9.6	0		0	5.5		6.6	0
1991	41.7	0	8.6		5%	9.6	0		0	5.4		6.7	0
1992	47.4	0	8.4		5%	9.6	0		0	5.2		6.6	0
1993	48.7	0	8.8		5%	9.3	0	6.6	0	5.3		0	0
1994	53.1	0	10.3		5%	9.6	0	6.6	0	5.9		0	0
1995	58.7	0	10.6		5%	9.6	0	6.8	0	6.0		0	0
1996	62.5	0	0	13.8	5%	11.4	0	6.8	0	0	0	0	0
1997	66.8	5.6	0	13.3	0	13.1	0	8.0	2.4	0	0	0	0
1998	75.5	5.6	0	13.3	0	17.0	0	9.3	3.4	0	0	0	0
1999	78.1	6.9	10.2	22.5	0	17.1	0	10.8	4.2	2.0	1.0	0	0
2000	85.3	6.9	12.8	37.2	0	19.2	0	12.1	4.2	2.6	2.2	0	0
2001	87.4	6.9	15.3	58.3	0	19.6	6.9	12.1	4.2	3.1	5.9	0	1.4
2002	89.6	6.9	17.9	60.1	0	21.6	6.8	12.1	4.2	3.6	6.1	0	1.4
2003	89.6	7.2	20.5	63.9	0	24.9	6.2	12.1	4.4	12.3	6.3	0	1.2
2004	89.5	7.2	20.5	65.4	0	26.4	6.3	12.1	4.4	12.3	6.5	0.5	1.3
2005	89.5	7.2	20.5	69.9	0	27.8	6.3	12.1	4.4	12.3	8.6	0.5	1.3

World Market Conditions: Price Setting and Vulnerability of Energy Intensive Industries

WP2

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2.1 Introduction

This chapter looks at market structure and the implications for the manufacturing sector of the introduction of environmental tax reform (ETR). The example of ETR that is used in this project is the introduction of an energy or carbon tax accompanied by re-spending of the revenues in a tax neutral manner. Such a reform was implemented during the nineties in seven EU countries. These are Denmark, West Germany, Finland, Netherlands, Sweden, the UK and Slovenia, which are called here the “ETR countries”.

Some manufacturing sectors can be particularly sensitive to energy/carbon taxation if they are users of large amounts of energy. To the extent that their products are traded on world markets, the tax could put them at a disadvantage vis-à-vis companies elsewhere. Competitive pressure would be especially strong if the competing establishments are in jurisdictions that have lower or no energy taxes, or have low emission standards in general – be this the result of low incomes, lack of concern or because these competitor countries are free-riding on Europe’s efforts to address global warming. Manufacturers in such competitor countries thus enjoy what amounts to a comparative advantage in cheap assimilative capacity.

The importance of this threat evidently depends on many factors, and it is often claimed that it is labour costs, access to raw materials and markets that are the main factors determining the profitability and location of companies. The other side of the debate focuses on energy intensive industries and paints highly threatening implications of actions to reduce greenhouse gases.

The debate has usefully pointed to issues that require to be addressed if vulnerability is to be properly assessed, in particular the issue of market structure. Market structure shapes the sector’s market power which, along with the extent of its energy use, its trade exposure and other things such as scope for adapting its technology, determines its vulnerability under ETR.

2.1.1 Market structure analysis

Vulnerability under ETR hinges in the first instance on energy intensiveness of the sector and its exposure to trade. How these impinge will also depend on the sector’s market power. Does the sector have market power? If the answer is ‘yes’ the competitiveness threat may not in fact be serious. On the one hand domestic manufacturers may face an international price for their product that they simply have to meet or else go out of business. On the other hand they may be price setters who can set prices as a mark-up on costs. When energy costs rise on foot of an energy tax, sectors that fall in the latter category are not vulnerable. A third possibility is that the sector’s market power lies somewhere between the two extremes, in which case it is not vulnerable to the same extent as those in the first.

There are various ways of measuring market power. One way is by looking at the degree of concentration in the industry, that is, the number of firms in the sector (Alanen, 1996; Jenkins, 1998; Whelan, 2003). The more concentrated the industry is in just a few firms the greater the ability to pass on cost increases to customers. Product differentiation is another indication of market power, though the measurement of product differentiation is less easy. The present study differs from previous analyses by offering an empirical analysis of actual price-setting behaviour in order to assess market power.

This study estimates market power directly by applying a model of price-setting behaviour to see whether the sector’s output price is determined by an ‘international price’ or, alternatively, as a mark-up on domestic costs, or a combination of the two.

Because relocation is also a possible option for firms confronted by energy taxes, the possibility that companies gravitate to countries with light pollution controls or low pollution taxes needs investigation – the so-called pollution haven hypothesis.

Potential technological adjustments are also important. Evidently, if companies have access to technology that enables them to abate their emissions cheaply, then their vulnerability under the energy tax will be less than initially perceived. The availability of abatement technology and its cost, in terms of the net marginal abatement costs for the sector, are crucial to the discussion on competitiveness and will be dealt with in the next work package and under the case studies. It is claimed that there are technologies that are worthwhile adopting in any event, though energy-intensive sectors have a tendency to have already adopted many energy efficiency measures that are available (Sorrell *et al*, 2004).

2.1.2 Outline of chapter

After a screening process, by which potentially vulnerable sectors are selected for further analysis, this work package gives detailed descriptions of these sectors, by looking at various features, in the ETR countries and non-ETR countries of the EU.

The empirical model for investigating market power is presented next. It is estimated for the selected potentially vulnerable sectors in the ETR countries. The resulting indications of price taking versus mark-up pricing by these sectors are discussed.

A summary of the literature on empirical analyses of the pollution haven hypothesis is given. This is enlarged by responses from agencies that would have had first-hand experience of the effects of ETR on industry location.

Having selected the energy intensive sectors and analysed their price-setting power, the possibility of grading vulnerability in several dimensions can be introduced. This shows how vulnerability to energy taxes can be graded, taking unit energy costs, price-setting power and potential technology adjustment jointly into account.

2.1.3 Potentially vulnerable sectors selected

Sectors that are potentially vulnerable include those that are high energy users and are exposed to trade. They could be vulnerable even where the revenues from carbon/energy taxes are directed to reduce labour taxes in a package of environmental tax reform, if the sectors have low or medium labour intensity.

The selection of vulnerable sectors that would be candidates for further analysis needed to take account of the above observations, as well as data availability in the other partner countries, and the need for a balanced mix of features. A strong representation of sectors with high energy expenditure shares was deemed desirable. A selection of sectors was made following discussions with partners, using the team's knowledge about country differences. The sectors selected are summarised in the table below.

Table 2.1: Potentially vulnerable sectors selected for further analysis

	NACE code	Characteristics - intensity			
		Energy exp	**Labour**	**Export**	**Import**
Food and beverages	15	high	low	low	low
Pulp, paper and board	21	high	medium	low	low
Wood and wood products	20	medium	low	low	low
Basic chemicals excl. pharmaceuticals	24 less 24.4	high	low	high	high
Pharmaceuticals	24.4	low	low	high	high
Non-metallic mineral products	26	high	medium	low	low
Basic metals	27	high	high	medium	medium

Source: Appendix 2.1, from UK *Input-Output Tables 2000*. Sectors were ranked by characteristics and split into three groups, high, medium and low intensity. Rankings differ slightly, according to dataset used. Food and beverages are borderline energy intensive, being the lowest of the high energy intensive sectors.

In making the selection the team took account of varying economic significance by country. For example, the export intensity of Wood and Paper from Sweden and Finland is high by contrast with that of other countries and this added weight to the inclusion of these natural resource sectors. The breakdown of Chemicals into two components, with Pharmaceuticals treated separately, enables these highly traded products to be covered in more detail. Pharmaceuticals are especially highly traded. The inclusion of Food and beverages provides a contrasting sector being in the high third in terms of energy expenditure intensity (though only just) but having low trade shares. Sectors with low labour intensity, that is, Food and beverages, Wood and wood products, and both parts of the Chemicals sector, could be vulnerable under ETR if revenue is recycled to reduce labour taxes. In addition to satisfying the major criterion of energy intensity, the selection took care to bring these other important considerations into account.

Where data allow, these seven sectors are the subject of analyses in the following sections where different aspects of vulnerability will be explored.

2.2 Energy expenditure and emissions intensity

The potentially vulnerable sectors are now described in more detail in order to help assess the effects of the tax element of environmental tax reform on competitiveness. Comparisons with All manufacturing will be made and, where data allow, the six ETR countries will be compared with another six 'non-ETR' countries.

2.2.1 Unit energy costs

The vulnerability of a sector to competitive pressures was assessed firstly according to what might be termed 'unit energy costs'. This is energy expenditure intensity and various aspects are explored now, including indices of each sector's position in relation to the average within the sector, across time and across countries. The time period under review is 1985 to 1998, which covers much of the period when ETR was being introduced or was under consideration.[1]

These unit energy costs are calculated with GVA (Gross Value Added) in the denominator[2] and energy inputs are measured in constant million 1995 euro. Expenditure on energy is made up of the cost in the manufacturing process in each sector of 11 different fuel types: Coal, Coke, Lignite, Heavy Fuel Oil, Middle Distillates, Natural Gas, Derived Gas, Electricity, Nuclear Fuels, Crude oil and Steam.

Table 2.2.1 Unit energy cost in selected sectors in 1998 (GVA basis)

% of GVA	Wood and Paper	Pharma-ceuticals	Basic Chemicals	Non-met mineral products	Basic Metals	Food, Beverages & Tobacco	Total Gross Manuf. Output
Denmark	2.4	3.3	4.8	6.8	17.7	5.4	4.6
Germany*	7.4	19.9	27.2	15.7	56.3	7.8	6.2
Finland	21.4	14.5	19.7	12.3	33.0	4.0	7.9
Netherlands	4.8	24.0	32.3	11.7	29.6	4.7	7.7
Sweden	8.6	15.2	20.4	16.2	29.4	5.8	4.6
UK	4.4	3.8	12.4	8.8	8.5	3.5	4.9
EU15	8.6	17.3	24.4	17.8	42.5	6.8	7.0
ETR (6)	8.0	16.7	24.4	15.0	14.4	6.0	6.5
Non ETR(6)	9.4	18.9	25.3	21.2	36.3	7.7	7.4

Note: ETR(6) are the EU countries that introduced environmental tax reform, namely, Denmark, Germany, Finland, the Netherlands, Sweden, and the UK. The non ETR(6) used here are Belgium, Spain, France, Italy, Portugal and Austria. * Data on Germany were only available for West Germany in this Work Package. *Source:* E3ME database, on GVA basis.

Wide variability aside, the Basic metals sector has consistently the highest unit energy costs across all countries except the UK and the Netherlands. The next most intensive sectors are Basic chemicals and Pharmaceuticals. Non-metallic mineral products are also shown to have above average unit energy costs compared to Total gross manufacturing but not as high as the sectors just listed. Compared to All manufacturing, gross value added in this sector tends to be lower in aggregate terms. Nevertheless its expenditure on energy is very significant across all countries involved.

The Wood and paper sector has some interesting variation across countries, indicating the heterogeneous nature of the sector. Germany has high-energy usage as well as Finland. For other countries examined within this sector, unit energy costs were found to be below the average for all manufacturing of the EU15.[3] As expected, the Food, beverages and tobacco sector had energy intensity levels below the manufacturing

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[1] This was due to the availability of energy data provided from the E3ME database by Cambridge Econometrics. The exchange rates used were the annual average exchange rates available from the EUROSTAT Ameco database.

[2] GVA (gross value added) is expressed at *basic* prices defined as the prices received by producers minus any taxes payable plus subsidies received as a consequence of production or sale. They are expressed in constant price terms, 1995=1.

[3] EU15 GVA is calculated as the aggregate of its members' GVA and the aggregate energy expenditure is expressed as a percentage of total EU15 GVA.

average in all countries. For this reason, this sector will be used as the low energy intensity sector for comparative purposes where called for. It also has least variation across countries.

Table 2.2.2 Ranking of countries according to unit energy cost (GVA basis) within each sector in 1998 (1=most intensive country; 6=least intensive country)

1998	Wood and Paper	Pharma-ceuticals	Basic Chemicals	Non-met mineral products	Basic Metals	Food, Beverages & Tobacco	Total Gross Manuf. Output
Denmark	6	6	6	6	5	3	5
W. Germany	3	2	2	2	1	1	3
Finland	1	4	4	3	2	5	1
Netherlands	4	1	1	4	3	4	2
Sweden	2	3	3	1	4	2	6
UK	5	5	5	5	6	6	4

Table 2.2.2 shows how consistent the ranking of unit energy costs is within each selected ETR country. Of the six ETR countries, we saw that Finland is the most intensive energy-user for the Wood and paper sector, where it spends two and a half times as much per unit of gross value added (21.4%) than the next most intensive energy spender which is Sweden (8.6%) and it is also the most intensive energy spender for All manufacturing. The Netherlands has highest unit energy costs in both Basic chemicals and Pharmaceuticals. Germany, Sweden and Finland follow behind in this order, spending close to 15 per cent of their GVA on energy inputs. However, there is a very significant drop in Basic chemicals in the two least intensive countries; Denmark and the UK, which each spend less than four per cent of GVA on energy inputs. The fact that Sweden ranks sixth (most extensive) in its All manufacturing contrasts with the relative intensity in these selected sectors in Sweden. The remaining manufacturing sectors that were not selected spend a signficiantly lower proportion of their value added on energy materials than do these six vulnerable sectors.

Some of the high figures prompt the questions: Is there compensation or special treatment for the Wood and paper sector in Finnish ETR? Is there some particular feature of the structure of the Basic chemicals sector in the Netherlands that does not apply to other Dutch sectors?

Index of Unit Energy Costs

A comparison of unit energy costs for the selected sectors is made with that of All manufacturing, within each country. This index is a ratio of sectoral to All manufacturing unit energy costs (GVA basis) in each country. The index equals 1 when a sector's unit energy cost is exactly equal to the average for all manufacturing for the corresponding year. In this way, this index measures the sector's unit energy cost vis-à-vis the average unit energy cost for all manufacturing in the country in question. Being a within-country index, average country-specific energy costs have been incorporated.

The following table shows that the value of the index for the Food, beverages and tobacco sector is less than unity in the EU15 as a whole though in Denmark, Germany and Sweden it is greater than unity. Next is the Wood and paper sector where the unit energy cost index for ETR countries is mixed, and greater than one for Finland, Sweden and Germany. This reflects the special nature of this sector in Scandinavia in particular. We will see that in Sweden and Finland, the Wood and paper index has been falling somewhat in later years, while the index has been fairly stable in Germany over the period studied.

According to this index, the sectors Basic chemicals and Basic metals can be classed as having relatively high unit energy costs for the selected sectors, as seen in Table 2.3.3. For all countries studied, the index for the selected sectors is greater than 1 and in many cases the sectors are over twice as energy intensive as all manufacturing in the respective countries. In Sweden, the basic metals sector has over six times more energy expenditure as a share of value added than the average for all manufacturing in Sweden. In Germany it is over eight times.
Non-metallic mineral products (including glass, cement and lime production) are also shown to have quite high unit energy costs, meaning that all countries have unit energy costs greater than for All manufacturing. This pattern did not change for any of the countries over the period studied.

Table 2.2.3: Average unit energy cost index (GVA basis) 1990-1998 (All Manufacturing = 1)

	Wood & Paper	Pharma-ceuticals	Basic Chemicals	Non-Met Minerals	Basic Metals	Food, Bev & Tobacco
DK	0.60	0.76	1.06	1.72	4.26	1.13
DW	1.20	2.88	4.02	2.59	8.10	1.21
FI	2.92	1.92	2.69	1.71	3.86	0.45
NL	0.61	3.12	4.36	1.37	4.18	0.65
SE	2.20	3.61	5.05	3.76	6.88	1.26
UK	0.91	0.74	2.35	1.80	1.87	0.69
EU15	1.28	2.35	3.44	2.57	5.92	0.98
Classification	Low	Medium	High	Medium	High	Low

The change in the index of unit energy cost relative to that of All manufacturing over the period 1990 to 1998 is shown in Table 2.2.4. Some interesting patterns arise. Sweden's relative unit energy costs have decreased across the board for all six sectors. This suggests that these sectors may have become more energy efficient (in expenditure terms) compared to all manufacturing. The improvement was very significant in the Non-metallic minerals sector, as it was in Denmark also. Except in the Netherlands, the Non-metallic minerals sector reduced its energy expenditure by a far greater amount than did All manufacturing. For all sectors in the UK the gains compared to All manufacturing were modest.

There were also notable increases in unit energy costs over the period. Germany increased its energy cost component of Basic metals by three times the average EU15 energy expenditure while in Basic chemicals and Pharmaceuticals German energy inputs also increased significantly – possibly due to increasing cost rather than quantity.

Table 2.2.4: Percentage points change in unit energy costs index, from 1990 to 1998

	Wood & Paper	Pharma-ceuticals	Basic Chemicals	Non-Met Minerals	Basic Metals	Food, Bev & Tobacco
DK	-0.12	0.00	-0.01	-0.57	-0.24	+0.15
DW	0.00	+0.84	+0.96	-0.07	+3.22	+0.10
FI	-0.33	-0.22	-0.50	-0.17	+0.22	+0.09
NL	+0.04	+0.32	+0.14	+0.47	-0.02	0.00
SE	-0.57	-0.33	-0.82	-0.66	-1.11	-0.04
UK	-0.05	+0.03	0.00	-0.07	-0.13	-0.04
EU15	-0.05	+0.43	+0.35	-0.05	+1.35	+0.01

2.2.2 Before and after ETR

The within-country patterns corresponding to the various national ETR reforms can be briefly sketched though further work on this follows in later chapters. The years of ETR implementation that are relevant, given in the previous chapter are:

Sweden 1991; Denmark 1995; Netherlands 1996;
Finland 1997; Germany 1999; UK 2001

In order to investigate the patterns, different data are used[4] that have some discontinuities with data previously used.

[4] Sections 2.2.2 and 2.2.3 use data from E3ME, version 4, October 2005.

Table 2.2.5 Change in unit energy costs (GVA basis) in 2002 since the year of ETR

	Wood & Paper	Pharma-ceuticals	Basic Chemicals	Non-Met Minerals	Basic Metals	Food, Bev & Tobacco
DK	29%	34%	-30%	79%	90%	11%
FI	8%	20%	-11%	-24%	4%	0%
GE	14%	15%	34%	35%	48%	20%
NL	45%	54%	80%	45%	62%	46%
SE						
UK*	-5%	-11%	-9%	-12%	-8%	-10%

Note: Swedish ETR occurred in 1991 and the data used here do not extend before 1993.
* UK figures are provisional.

The immediate effect of the introduction of an energy tax will be to increase the unit energy cost, all else equal. However, a substitution effect may dominate if fuel switching towards lower-taxed fuels or technology adjustment occurs. Table 2.2.5 shows a dramatic increase in energy expenditure in Denmark following the 1995 reform and suggests that neither fuel switching nor technology upgrading occurred immediately. On the other hand, total unit energy costs in the UK have decreased since 1999, the year of announcement. In the light of the opposing forces, changes in energy expenditure need to be decomposed to highlight changes in *physical* fuel consumption. Another data issue is that of sector-specific energy prices (e.g. encompassing prefential pricing/bulk buying discounts etc) which are usually not captured in energy data.

Physical energy consumption data, as opposed to energy expenditure data, are available from Eurostat by fuel-user categories, with slight industrial classification differences. Table 2.2.6 presents the average annual change in physical energy consumption before and after ETR, for sectors that are most closely related to the selected vulnerable sectors. Sectors Wood and wood products and Pharmaceuticals are obvious absentees from the following analysis.

The information shown in Table 2.2.6 will be extended in later chapters. It shows mixed results. Thirteen out of 25 post-ETR changes in energy consumption show declines. The most concentration of post-ETR declines occurs in Iron and steel and Food, drink and tobacco. Most declines occur in Denmark and Germany, though Germany has one spectacular increase in energy consumption in Chemicals. The earlier decline may have been an announcement effect. With the run of years in some cases being so short and the absence of scaling by output a lot of weight should not be attached to these results, but they serve as a forerunner of analyses to come.

Table 2.2.6 Average annual change in energy consumption (physical energy) by fuel-user sector: before and after ETR

	Iron and Steel	Chemicals	Mineral Products	Food, Drink & Tobacco	Paper and Pulp
(ETR date)	Between 1990 to ETR date:				
Denmark* (1995)	-0.7%	-1.5%	5.9%	2.1%	-6.6%
Germany (1999)	-1.3%	-5.1%	-1.5%	-1.5%	3.4%
Finland (1997)	3.0%	2.4%	-8.3%	-1.3%	3.4%
Netherlands (1996)	1.4%	-2.8%	-1.9%	3.0%	0.5%
Sweden (1991)	-	-	-	-	-
UK (2001)	-2.7%	3.6%	-4.2%	-0.1%	1.0%
	Post-ETR to 2003:				
Denmark*	-1.5%	0.7%	-1.3%	-2.4%	0.7%
Germany	-4.4%	5.6%	-1.6%	0.5%	0.2%
Finland	0.1%	-4.0%	-1.7%	-6.0%	4.9%
Netherlands	-0.4%	4.1%	-1.3%	2.4%	5.0%
Sweden	1.8%	-0.9%	-1.8%	0.0%	1.3%
UK	5.3%	-0.3%	-1.3%	-0.3%	6.0%

Source: Eurostat Figures for Denmark are provisional.

2.2.3 Comparing ETR and non-ETR countries

Again a brief comparison of unit energy costs can be made between the same sectors in countries that have and have not yet experienced environmental tax reform. Energy expenditure within the sectors is expressed as a share of gross value added and thus the effect of sector size has been taken into account in the construction of the average figures shown in Table 2.2.7.

Table 2.2.7 Average unit energy costs (GVA basis) in ETR vs non-ETR countries, 1993 to 2002

% of GVA	Wood & Paper	Pharma-ceuticals	Basic Chemicals	Non-Met Minerals	Basic Metals	Food, Bev & Tobacco
ETR						
Denmark	6.8	1.3	1.4	14.6	11.8	8.0
Germany	10.9	18.0	20.6	15.6	31.3	8.5
Finland	15.8	13.2	25.8	6.7	25.9	6.8
Netherlands	6.9	0.1	36.6	7.7	14.4	5.0
Sweden	3.3	0.5	18.0	8.3	15.8	3.3
UK	4.9	2.4	13.2	10.9	22.9	4.9
Non ETR						
Belgium	13.3	0.1	41.8	15.8	21.3	7.5
Spain	6.6	18.8	16.9	15.1	21.5	5.6
France	8.0	0.2	19.9	9.9	17.5	5.8
Italy	14.4	0.2	24.3	18.5	39.7	6.3
Austria[5]	8.3	19.7	27.1	10.9	30.6	6.8
Portugal	11.9	0.1	n.av.	42.3	17.8	7.3

Source: E3ME V4 (Oct 2005 update). Figures are not comparable with those in Table 2.2.1.

Within sectors the table shows some considerable variation in unit energy costs across countries. Taking the figures overall they are lower for ETR countries, particularly perhaps when the sector occupies a substantial share of all manufacturing within a country. For instance, the Pharmaceuticals sector constitutes a significant proportion of all manufacturing in the Netherlands, where the unit energy cost is low. Typically, unit energy costs are lowest for the Food, beverages and tobacco sector, which also show little variation between ETR and non-ETR countries and within these groupings. Basic metals and Non-metallic minerals stand out in having apparent higher unit energy costs in non-ETR countries compared to ETR countries. The question naturally arises as to whether or not it was the less energy intensive countries that introduced ETR.

Finally in this foretaste of later analyses of ETR, Table 2.2.8 shows the change in physical units of energy (absolute amounts) consumed in 2003 compared to 1990 with comparison between ETR and non-ETR countries. There is no scaling for economic activity of the sectors over time in this table. The table indicates that ETR countries tended, on average, to have achieved higher levels of energy saving than the average for non-ETR countries, in each sector except in Iron and steel. This is in line with previous tables where this sector appears consistently to be using more energy in 2003 than in 1990. However, 2003 was a year of exceptional demand for iron and steel and the increased output effect has not been allowed for in this table.

[5] Austria was selected as a non-ETR country though as Chapter 1 states it may be said to have implemented an "implicit" ETR.

Table 2.2.8 Energy consumption by sector in 2003 (physical units, 1990=1) ETR versus non-ETR countries

(1990=1)	Iron and Steel	Chemicals	Mineral Products	Food, Drink & Tobacco	Paper and Pulp
ETR Countries					
Denmark	0.81	0.97	1.19	0.91	0.74
Germany	0.76	0.68	0.81	0.86	1.38
Finland	1.20	0.73	0.38	0.55	1.61
Netherlands	1.03	1.15	0.73	1.35	1.39
Sweden	1.23	0.91	0.70	0.91	1.16
UK	1.23	1.43	0.59	0.98	1.16
Average ETR	***1.04***	***0.98***	***0.73***	***0.93***	***1.24***
Non - ETR					
Belgium	0.84	1.20	1.06	1.49	1.68
Spain	1.21	1.39	1.74	1.84	2.30
France	0.86	1.07	0.85	1.22	1.30
Italy	0.98	0.75	1.16	1.78	1.52
Portugal	0.58	1.36	1.31	1.24	2.97
Austria	1.63	1.65	1.22	1.49	1.20
Average Non-ETR	***1.02***	***1.24***	***1.22***	***1.51***	***1.83***

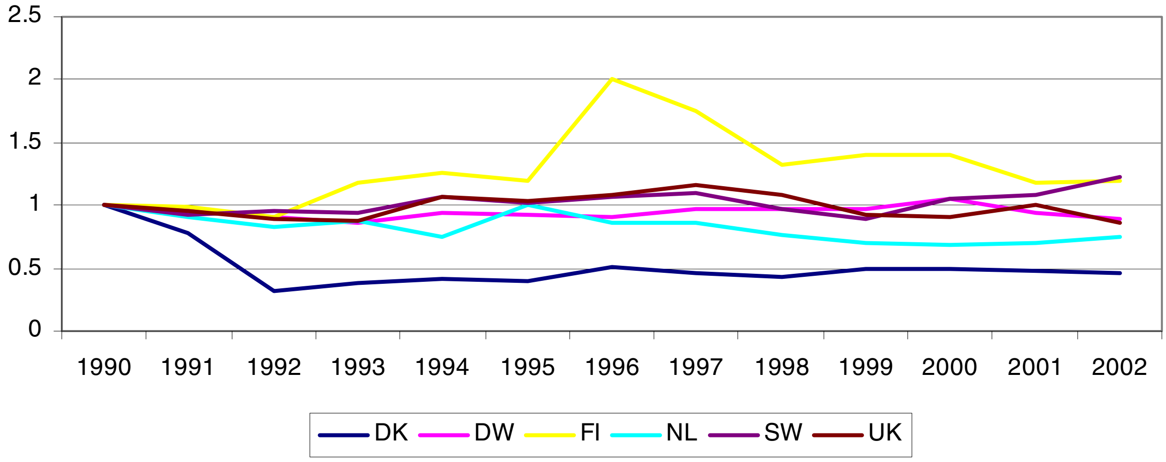
Source: Derived using Eurostat data

2.2.4 Sectoral Emissions

Using 1990 as the base year, the following figures show the change in emissions of CO_2 from their 1990 levels, 1990 being the baseline year under the Kyoto Protocol.

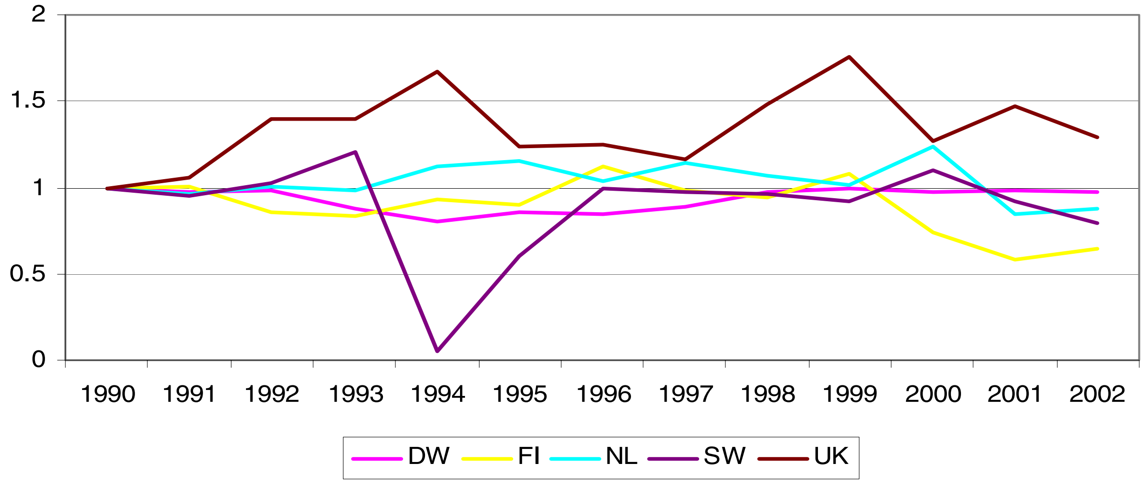
Looking at the Iron and steel sector, Finland is the only country where the CO_2 emission levels from this sector have been significantly above their 1990 levels. Denmark's Iron and steel sector made very significant reductions in the years following 1990 and maintained these levels.

Figure 2.2.1 Iron and Steel Emission levels of CO_2



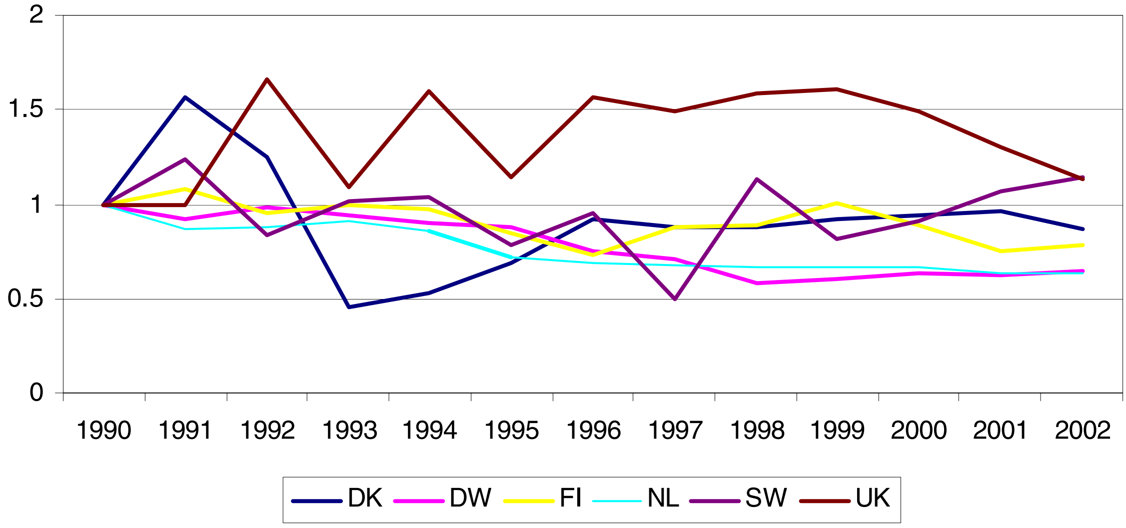
In Non-ferrous metals, the UK stands out as having increased emissions and has shown a great deal of variation since 1990.

Figure 2.2.2 Non-ferrous Metals Emission levels of CO_2



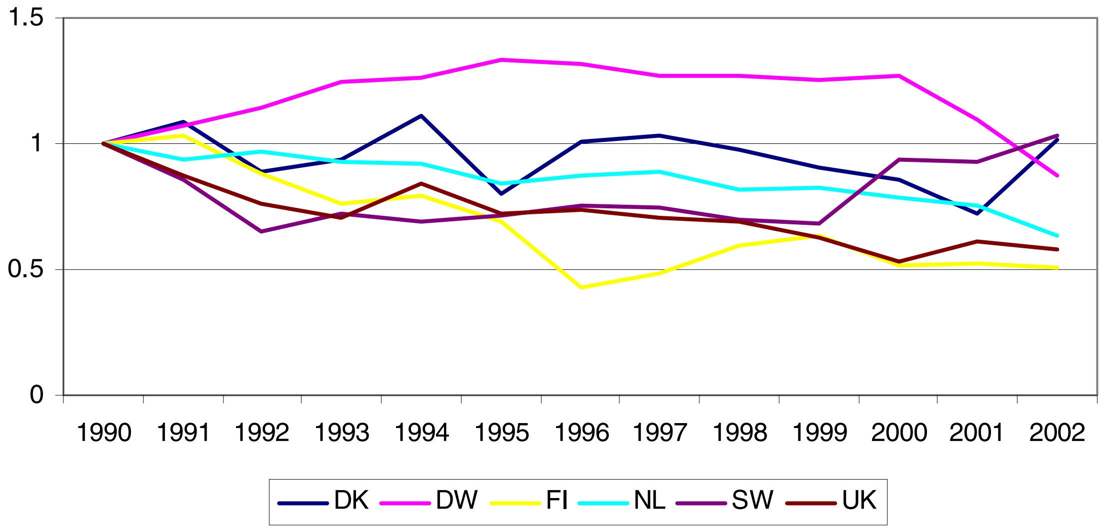
The emissions situation for Chemicals has been much more varied over the period 1990 to 1998 and became more settled thereafter. The pattern for the UK is singularly varied, peaking in 1998, but in recent years the emissions level has trended downwards. In 1991, the Danish Chemicals sector peaked but has fallen dramatically since. All other countries display lower emissions levels at the end of the period than at the beginning.

Figure 2.2.3 Chemicals Emission levels of CO_2



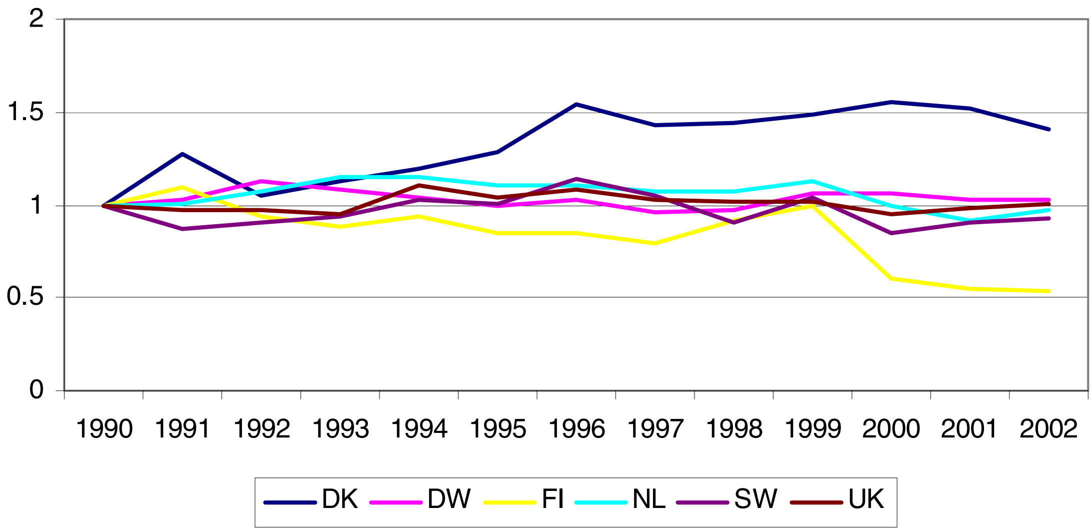
The Non-metallic mineral products sector, which includes glass, cement and lime production, by 2002 displays similar or significantly reduced emissions compared to 1990. Danish emissions appear to be hovering around their 1990 levels while the German sector having increased its emissions is now on a downward path. Finland achieved the most dramatic reductions up until 1996 but these reductions have slackened and emissions have stabilised at about half of what they were in 1990.

Figure 2.2.4 Non-metallic Mineral Products Emission levels of CO_2



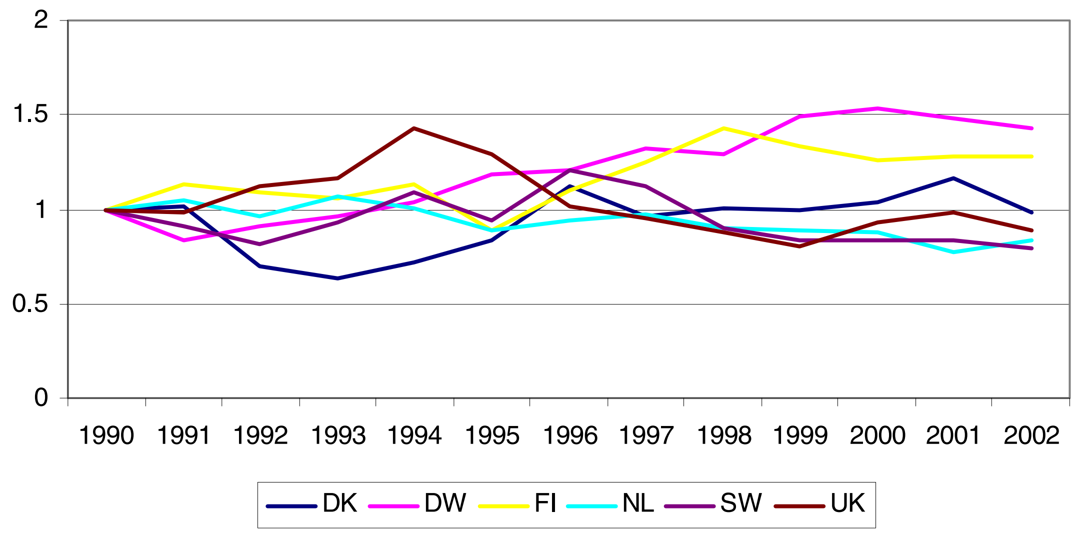
Emissions of CO_2 from the Food, Drink and Tobacco sector exhibit the most stable pattern of all the sectors studied. Only Denmark shows strong increases over the period.

Figure 2.2.5 Food, Drink and Tobacco Emission levels of CO_2



Emissions from Paper and pulp across ETR countries are shown in Figure 2.2.6. For Germany and Finland, there is evidence that emissions of CO_2 increased steadily between 1995 and 1999 and levelled off afterwards possibly in response to their environmental tax reforms of 1997.

Figure 2.2.6 Paper and Pulp Emission levels of CO_2



The CO_2 emissions in 2002 for the ETR countries are given along with those of non-ETR countries in Table 2.2.9 below. These are not expressed as a share of output activity within the various sectors for reasons of the sector incompatibility among the data outlined above, so that scaling is absent.

Table 2.2.9 Change in sectoral emissions of CO_2 by 2002 (1990=1)

	Iron and Steel	Non Ferrous Metals	Chemicals	Mineral Products	Food, Drink & Tobacco	Paper and Pulp
ETR:						
Denmark	0.46	-	0.87	1.01	1.41	0.99
Germany	0.89	0.98	0.64	0.88	1.03	1.43
Finland	1.19	0.64	0.79	0.51	0.54	1.28
Netherlands	0.75	0.88	0.64	0.64	0.97	0.84
Sweden	1.24	0.79	1.14	1.03	0.93	0.80
UK	0.86	1.29	1.13	0.58	1.00	0.89
Average	***0.89***	***0.92***	***0.87***	***0.78***	***0.98***	***1.04***
Non- ETR:						
Belgium	0.77	0.85	1.32	0.77	0.86	0.86
Spain	0.58	1.51	0.89	0.92	1.10	1.11
France	0.88	0.51	0.79	0.69	1.40	0.62
Italy	0.65	1.40	0.39	0.67	1.84	1.09
Portugal	1.03	3.05	1.91	0.72	1.62	0.76
Austria	0.31	0.16	0.39	0.60	0.50	0.36
Average	***0.70***	***1.25***	***0.95***	***0.73***	***1.22***	***0.80***

Source: E3ME data V4, Oct 2005

The pattern is mixed. ETR countries show lower increases in emissions between 1990 and 2002 in the case of three sectors, and higher increases in another three sectors. The Paper and pulp sector has increased emissions, owing to increases concentrated in Germany and Finland. With respect to Iron and Steel the increases were concentrated in Sweden and Finland. Among non-ETR countries, Italy's, Spain's and especially Portugal's Non-ferrous metals sectors showed increases.

2.3 Unit Labour costs

Unit labour costs, or 'labour intensities', are a key factor in determining the economic profitability of a sector within a country. In this section the selected vulnerable sectors are assessed in terms of their unit labour costs, that is, the share of expenditure on labour (wages and salaries) in Gross Value Added. Apart from their use in analysing competitiveness generally, when ETR includes reducing labour taxes unit labour costs that are high afford most scope for potential 'revenue recycling'.

Table 2.3.1 Unit labour costs (gross value added basis), 1998

% of GVA	Wood and Paper	Pharma-ceuticals	Basic Chemicals	Non-met mineral products	Basic Metals	Food, Beverages & Tobacco	Total Gross Manuf
Denmark	54.3	40.8	39.8	33.8	59.9	57.7	55.5
W. Germany	45.5	51.3	47.1	45.8	52.0	31.9	35.2
Finland	35.9	31.1	29.9	37.7	25.0	42.8	43.4
Netherlands	55.7	25.4	23.6	44.1	51.9	38.0	48.7
Sweden	27.9	22.6	21.7	34.3	34.0	30.0	45.3
UK	71.2	57.3	56.8	69.2	63.4	36.3	55.9
EU15	51.5	44.6	41.8	51.0	50.1	35.9	41.4
ETR (6)	49.6	45.2	42.5	49.9	59.5	35.0	43.4
Non ETR(6)	53.8	44.8	42.0	53.6	43.8	37.5	39.3

Table 2.3.1 shows the share of gross value added that is accounted for by expenditure on labour in 1998. With the exception of Germany and the UK, unit labour cost was lower in both chemical sectors compared with Total gross manufacturing. It is also found unit labour cost were was consistently lower than the average for Total manufacturing in the case of the Food, Beverages and Tobacco sector except for Denmark. A sizable difference between ETR and non-ETR countries occurs for Basic metals, where interestingly ETR countries are more labour intensive. This could faciliate ETR introduction, depending on the revenue recycling method chosen.

There are some instances of 'trade-offs' with energy expenditure of Table 2.2.1, in that high energy intensity relative to other ETR countries, prevails alongside relatively low labour intensity. Examples of this are the Wood and Paper sector for Finland and the Basic Metals sector for Germany. Where there is low energy intensity relative to other ETR countries, there are some instances of above average labour intensity, for example, in all sectors in the UK. Table 2.3.2 presents the ranking of countries by labour intensity within sectors.

Table 2.3.2 Ranking of countries according to unit labour costs (GVA basis), 1998 (1 = least labour intensive country)

GVA	Wood and Paper	Pharma-ceuticals	Chemicals	Non-met mineral products	Basic Metals	Food, Beverages & Tobacco	Total Gross Manuf. Output
Denmark	4	4	4	1	5	6	5
W. Germany	3	5	5	5	4	2	1
Finland	2	3	3	3	1	5	2
Netherlands	5	2	2	4	3	4	4
Sweden	1	1	1	2	2	1	3
UK	6	6	6	6	6	3	6

For the selected sectors Sweden is generally least labour intensive. The UK is generally most labour intensive, with Denmark and Germany somewhat behind. The classification of sectors within each country according to the indices of unit labour costs (labour intensity on a GVA basis) is given in Table 2.3.3. For each country, the index for each sector is calculated in the same manner as the index of unit energy cost given previously (Table 2.2.3), that is, it is expressed as the unit labour cost relative to the unit labour cost recorded for all manufacturing within that country.

Table 2.3.3: Unit labour cost index 1990-1998 (GVA basis, All Manufacturing = 1)

	Wood & Paper	Pharma-ceuticals	Basic Chemicals	Non-met Minerals Products	Basic Metals	Food, Bever & Tobacco
DK	1.10	0.77	0.73	0.67	0.67	0.51
DW	1.29	1.47	1.39	1.19	0.64	0.35
FI	0.93	0.79	0.75	0.95	0.30	0.44
NL	1.22	0.60	0.57	0.90	0.61	0.44
SE	0.72	0.54	0.51	0.76	0.37	0.29
UK	1.25	1.09	1.04	1.14	0.66	0.38
EU15	1.28	1.15	1.09	1.18	0.59	0.38
Classification with-in selected sectors	High	Medium	Medium	High	Low	Low

The average unit labour cost of the EU15 is very close to that recorded for the ETR countries and is therefore not shown here. Revenue recycling under ETR that reduced labour costs could benefit most the sectors classified here as 'High', relatively speaking. That is, Wood and paper and Non-metallic mineral products would fare better than Pharmaceuticals and Basic chemicals, and in turn better than Basic metals and Food, beverages and tobacco.

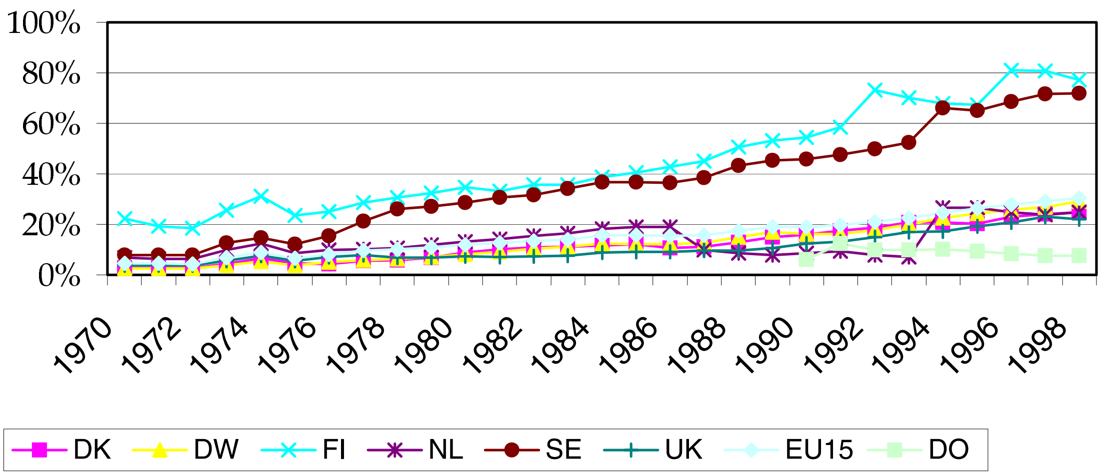
2.4 Trade Patterns

This section examines trade patterns and intensities for the potentially vulnerable sectors that were selected. An assessment of export and import intensity is undertaken. The origin and destination of trade is recorded with respect to trade within and outside the EU.

2.4.1 Export Intensity (output basis)

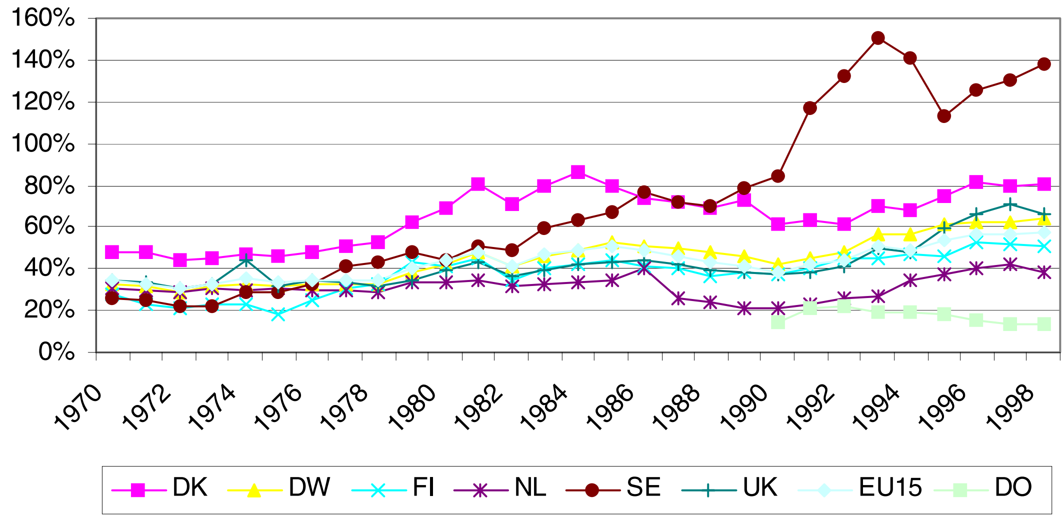
A measure of export intensity is calculated as the share of exports in the total value of output. The data, expressed in million units of domestic currency over the period 1970 to 1998, was provided from the E3ME database and the calculation was applied to each ETR country.

Figure 2.4.1 Wood and Paper Export Intensity



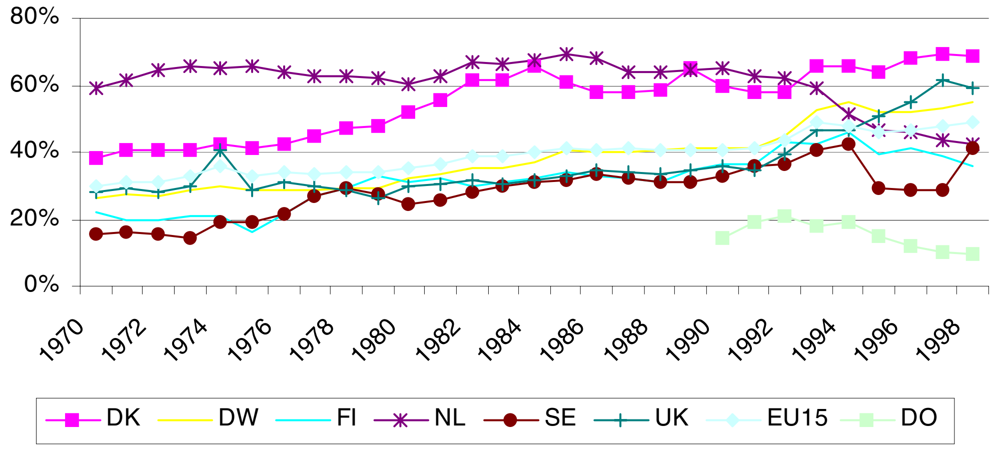
Finland and Sweden are distinguished exporters of Wood and paper products, with over 70 per cent of their domestic production exported in 1998. Export intensity for this sector has been increasing steadily during the period of study. Export intensity in the Netherlands took a sharp fall from 1987 to 1995, since when this sector has seen fairly stable export intensity for all other countries examined.

Figure 2.4.2 Pharmaceuticals Export Intensity



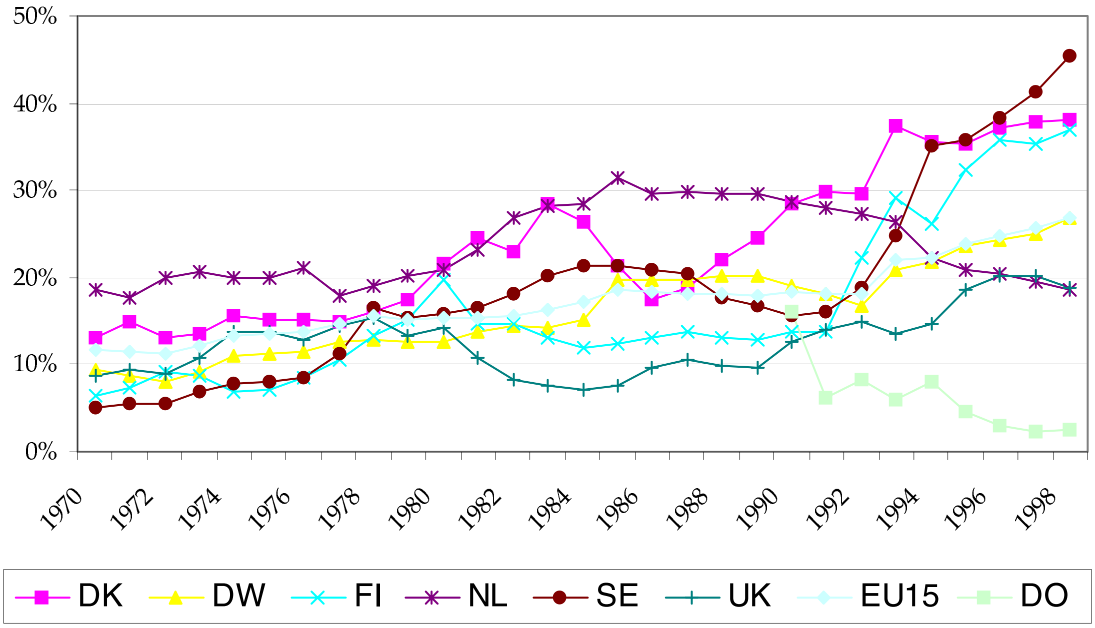
Sweden is by far the most intensive exporter of Pharmaceuticals exporting over 100 per cent of production since 1990. A possible explanation is the difficulty in distinguishing the country of origin from the country of despatch in the compilation of trade statistics, and the discrepancies that arise in transferring from trade classification (SITC) to NACE classification. Most countries have increased their export intensities of pharmaceuticals over the nineties.

Figure 2.4.3 Basic Chemicals Export Intensity



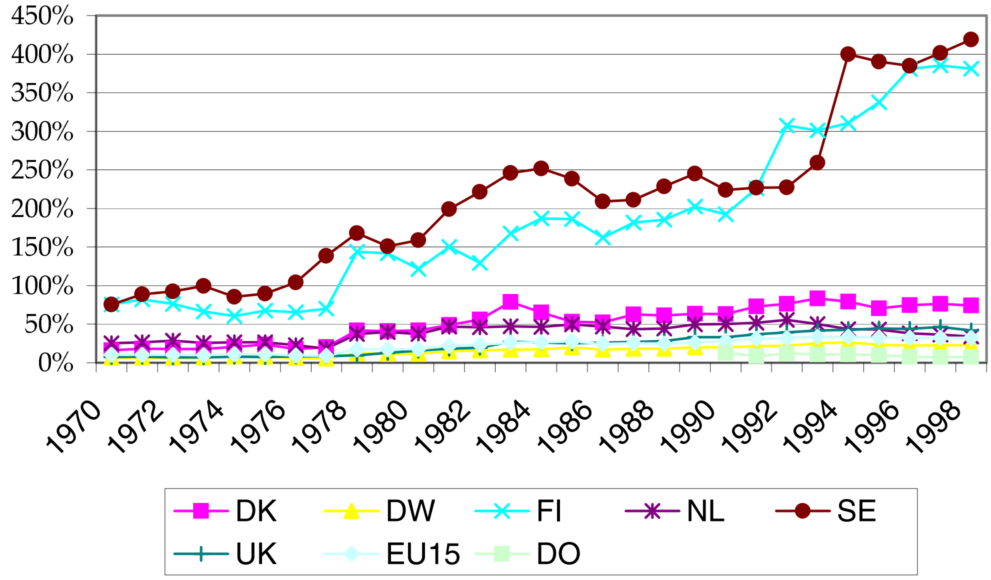
From 1970 to 1992, the Netherlands was the most export-oriented with respect to Basic chemicals. Its export intensity has declined since then, matched seemingly by the rise for the UK, while Sweden experienced a sharp dip during 1995 to 1997.

Figure 2.4.4 Non-metallic Mineral Products export Intensity



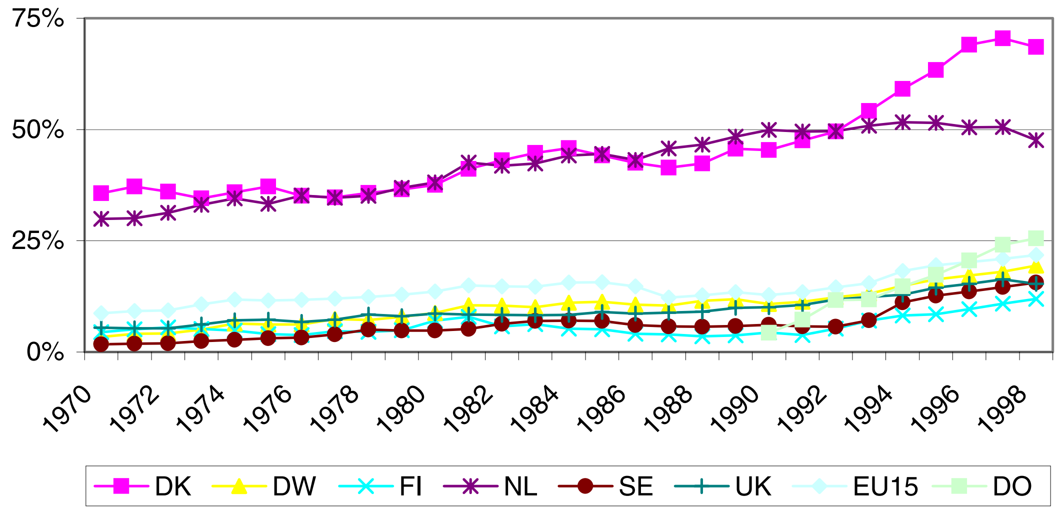
For Non-metallic mineral products one should note the change in scale of export intensity, given by the Y axis. This share of output traded is much less than that in other sectors studied. The Scandinavian countries, Sweden, Denmark and Finland, traded most with export intensities over 35 per cent, but not greater than 45 per cent of the value of output.

Figure 2.4.5 Basic Metals export intensity



By contrast with Non-metallic mineral products, the Basic metals sector is highly traded, with Sweden and Finland exporting between three and four times their national production of Basic metals. The reasons for this may be related to double counting or re-exporting patterns where, for various reasons, goods are imported and with very little additional processing are re-exported. This is a frequent feature in trade statistics.

Figure 2.4.6 Food, Beverages and Tobacco export intensity



Most ETR countries have relatively low export intensity in the Food, beverages and tobacco sector. The exceptions are Denmark and the Netherlands which export significant proportions of their national production from this sector – beverages (beer) are likely to be a significant component. All countries except the Netherlands have seen the export share rise since the early 1990s, but for most ETR countries this proportion remains below a quarter of all production with the exception of Denmark and the Netherlands. For these two exceptions apart, this sector is not highly traded.

2.4.2 Import Intensity

The import intensity ratio for each sector is calculated as the value of product imports as a share of home demand (home demand is Output + Imports - Exports).

Table 2.4.1 Import intensity ranking 1970 - 1998

	Rank (1970)	% Change 1970-1998	Rank (1998)
Pharmaceuticals	2	+54%	1
Basic Chemicals	1	+12%	2
Basic Metals	4	+23%	3
Wood and Paper	3	+16%	4
Non-Metallic Mineral Products	5	+13%	5
Food, Beverages and Tobacco	6	+15%	6
All Manufacturing		+4%	

For each sector, Table 2.4.1 ranks import intensity averaged across ETR countries in 1970 and 1998. All sectors studied increased their import dependency at a faster rate than the average rate for all manufacturing. Pharmaceuticals increased at the fastest rate (+54%) and this explains how it overtook Basic Chemicals in the import intensity ranking between 1970 and 1998.

2.4.3 Intra-EU and Extra-EU Trade

In general there would be less concern about the effects of ETR on trade with other countries that have introduced ETR than with those that have not introduced ETR. Estimates of trade within the EU are interesting because a high share of trade being intra-EU trade would make it easier for EU countries as a whole to introduce ETR.

Table 2.4.2 presents the proportion of imports that came from EU member states in the period 1990 to 1998 by sector for ETR countries and for the EU15. The results show a very high concentration of imports from EU neighbours. Most of the selected sectors have a higher propensity to import from the EU than does all manufacturing – shown by the EU import intensity for total gross manufacturing. The UK has a generally low import intensity from the EU. Denmark has consistently higher imports from the EU, except in the case of Food, beverages and tobacco, than have all EU members.

Table 2.4.2 Imports from EU as a share of country imports (average 1990-1998)

	Wood and Paper	Pharmaceuticals	Basic Chemical	Non-met mineral products	Basic Metals	Food, Beverages & Tobacco	Total Gross Manuf.
Denmark	1.02	0.89	0.89	0.95	0.94	0.68	0.77
W. Germany	0.84	0.78	0.78	0.69	0.66	0.79	0.66
Finland	0.88	0.86	0.86	0.68	0.67	0.81	0.70
Netherlands	0.89	0.76	0.76	0.82	0.77	0.77	0.69
Sweden	0.92	0.86	0.86	0.78	0.75	0.83	0.75
UK	0.83	0.83	0.83	0.64	0.68	0.76	0.67
EU15	0.90	0.86	0.86	0.70	0.73	0.81	0.74

The proportion of exports from the selected sectors that goes to EU destinations is spelt out in Table 2.4.3.

Table 2.4.3 Proportion of all exports that goes to EU destinations (1990-1998)

	Wood and Paper	Pharmaceuticals	Basic Chemical	Non-met mineral products	Basic Metals	Food, Beverages & Tobacco	Total Gross Manuf.
Denmark	0.89	0.55	0.54	0.84	0.92	0.70	0.69
W. Germany	0.78	0.63	0.63	0.77	0.69	0.73	0.63
Finland	0.75	0.47	0.46	0.64	0.80	0.39	0.64
Netherlands	1.84	0.67	0.66	0.76	0.76	0.81	0.73
Sweden	0.91	0.81	0.80	0.93	0.87	0.64	0.76
UK	0.61	0.64	0.64	0.56	0.68	0.62	0.64
EU15	0.81	0.66	0.66	0.67	0.75	0.78	0.68

Again, the UK tends to have a lower share of exports going to the EU than do other ETR countries. Wood and paper is very dependent on the EU as an export destination, while the pattern for Pharmaceuticals is not very different from that for Basic chemicals. There is a low export connection between Finland and the EU in the case of Food, beverages and tobacco and the Netherlands' export share of Wood and paper to the EU suggests an issue with data recording similar to that mentioned above and to the fact that major shipping entrepot ports are located in the Netherlands. Sweden has consistently very high reliance on the EU for its exports in these key sectors and its reliance is significantly higher for Wood and Paper. Again Pharmaceuticals and Basic chemicals have similar patterns across countries, which could be related to data classification issues. Exports of Non-metallic mineral products, which are expected to have high weight to value, are traded strongly intra-EU, relative to all manufacturing.

2.5 Price Setting Power

2.5.1 Literature review and model used in analysis

Where firms operate in a perfectly competitive market they are price takers on that market and the price equals the marginal cost of production. However, in many cases firms may operate under imperfect competition having a degree of market power. In this latter case firms may be expected to set their prices as a mark-up on cost, with the mark-up on cost reflecting the shape of the demand curve that they face. Where firms have market power and are able to discriminate between markets, producers will maximise profits by charging different prices in each market.

Price setting behaviour by firms has been the subject of intensive research in the literature over the past 30 years. Calmfors and Herin (1978) showed that while some Swedish firms exposed to international competition were price takers others were less dependent on world market prices. Pricing to market is a well-established phenomenon (Krugman, 1987) and there is evidence of its importance in explaining price changes in small open economies (Naug and Nymoen, 1996). Callan and Fitz Gerald (1989) show how Irish firms' pricing decisions changed over the 1980s with the advent of the EMS and the growing importance of the EU market; increasingly Irish firms' pricing decisions were determined by German producer prices (and the bilateral exchange rate). Friberg and Vredin (1996) show how pricing behaviour by Swedish firms evolved over time with a reduction in the proportion pricing in Swedish crowns and an increase in the proportion invoicing in foreign currencies.

Thus it is an empirical question, tested in this paper, whether firms in a particular sector in a particular country are price takers or whether they have market power, setting their own prices in a manner such that they can pass on at least some of any changes in domestic costs.

In this section the market price-setting power of the selected sectors is assessed for the ETR countries, namely, Denmark, Germany, Finland, the Netherlands, Sweden and the UK. Ireland is included for interest. The aim is to understand the global market context and ask whether the sectors were vulnerable to competition or not. Specifically, this analysis will establish by reference to past behaviour which sectors can 'pass on' cost increases, such as environmental taxes, or whether these must be absorbed in order to maintain sectoral output prices unchanged, showing that the sector is a price taker.

Two polar cases of the pricing of domestic manufacturing output can be posited, where prices are either:

- externally determined, and the sector is a price taker, or
- determined as a mark-up on domestic costs, and the sector is a price setter.

In the latter case the sector has market power and is less exposed to competitive pressures and less vulnerable in the event of the introduction of the tax element of ETR, such as a carbon tax. The carbon tax can be passed on by the firms that are price setters. If on the other hand the former case holds and prices for the sector's product are externally determined, then that sector could indeed be vulnerable in the event of the introduction of a carbon tax, in the absence of adequate mitigating measures such as revenue recycling that reaches the sector or if there exist no worthwhile options such as technological adaptations.

As background to the model one may start with a perfectly competitive market, where the law of one price holds. Using p_i to denote the domestic price of sector i's product, and $p_i^{\,f}$ to denote the foreign price expressed in domestic currency, then in the perfectly competitive situation:

$$p_i = p_i^{\,f}$$

but nevertheless in an oligopolistic situation profit-maximising firms set prices as an optimal mark-up over marginal costs,

$$p_i = mc_i + \mu_i$$

where mc_i is the marginal cost and μ_i is the mark-up, which can be zero. If we can assume that firms are not reacting to short-term price changes due to firm entry to the sector, this relationship should reflect the two sets of influences on the setting of output price. The following model could therefore be estimated.

$$p_i = \alpha_0 + \alpha_1 mc_i + \alpha_2 p^f_i$$

One could thereby test for evidence that prices are either set domestically i.e. according to domestic costs, or otherwise set by the foreign price. In the results from estimating this equation, three separate outcomes are of interest: the coefficient on domestic costs, α_1, is significant and non-zero, only α_2 is significant so that domestic costs do not drive the prices set by the sector (only the external price situation matters), or a mixture of the two.

The equation above is taken to be a long-run price relationship. It is consistent with perfectly competitive markets that require goods to be perfect substitutes. It is plausible that in some markets there is room for market power to hold but there is a limit on price divergence in the long run. This is because at sufficiently high domestic prices all markets are contestable such that entry can occur.[6]

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[6] Obstfeld and Rogoff (2000) show that declining transport costs can have a big impact on relative demand for domestic and foreign goods (and thus explain the falling 'home trade bias puzzle'), and therefore on relative prices – this could justify a time trend but it is not used in the following analysis.

If estimated coefficients on domestic costs are insignificant, the sector is likely to be a price taker and therefore subject to competition. If the estimated coefficients on foreign prices are insignificant the sector is likely to be immune from competition from abroad. Some mixture of the two is possible. The US, as a dominant trading bloc can be taken as representing the world, or as country *j*.

Purchasing power parity (PPP) is imposed for the long-run structural relationship between exchange rates and foreign prices.

The basic model then becomes:

$P_d^* = f(P_j, R_j, W_k)$

Where P_d^* = the long-run wholesale price for the sector's domestic output in domestic currency terms
P_j = the wholesale price index in the 'competing' country or bloc *j*
R_j = the exchange rate with country or bloc j
W_k = the price index for domestic input factor *k*. Wage rates are used.

The US price as the 'world price' is used for the price in 'competing' country j, and in a second run the German price is used as the 'competing' country price. To allow for differential short-run responses to changes in prices and exchange rates, a lagged response is allowed, by inclusion of an error-correction type term.[7] Equations are estimated for each sector for each country investigated. Data are quarterly and run mainly from 1975 to 2002/3 and were sourced from the OECD and Eurostat.

2.5.2 Results

The aim of this analysis was to assess the nature of market conditions for the sectors identified in the screening section above by determining whether or not they face competition. The basic model above was tested on the data. Table 2.5.1a shows the results for the coefficients and their significance levels. These are lambda (the speed of adjustment), domestic cost (country manufacturing wage), and foreign output price in US dollars (PPP imposed). Estimation is across the six selected sectors (Pharmaceuticals not being separated from Chemicals) and six ETR countries. A measure of fit is given by the adjusted R2. Table 2.5.1b shows the equivalent analysis with the German as opposed to US price used to represent the foreign price.

At the base of each table are rows labelled 'result'. For each sector, these give the number of countries for which the domestic cost and the foreign price was significant determinants of price.

[7] The error correction representation is:

$$\Delta Y_t = \alpha_1 + \lambda(Y_{t-1} - \beta_1 X_{t-1}) + \sum \alpha_2(i)\Delta y_{t-i} + \sum \alpha_3(i)\Delta X_{t-i} + \varepsilon_{yt}$$

where β = parameters of the cointegrating vector, Lambda λ is the speed of adjustment parameter where a higher value indicates a faster convergence from short-run dynamics to the long-run situation, and ε_{yt} = white-noise disturbance with no moving average part and α_i are all parameters. Appendix 2.5 discusses modelling issues and describes the data and econometric tests.

Table 2.5.1a Modelling the domestic output price - with US price representing the foreign price[1]

-Adjustment speed λ -Domestic cost -Foreign price -Fit: Adjusted R^2	Chemicals	Food, Beverages and Tobacco	Non-metallic Mineral Products	Paper and Paper Products	Wood and Wood Products	Basic Metals
Denmark	-0.128*** 0.043 0.137 0.262	-0.050** 0.164 0.295* 0.388	0.009 1.377 -0.920 0.540	-0.028 0.224 0.639 0.453	-0.045 0.421 0.151 0.359	-0.062** 0.174 0.643*** 0.323
Germany	-0.137** 0.381*** 0.174 0.492	-0.012 0.242 0.517 0.143	-0.022 0.079 -0.327 0.498	-0.044*** 0.361*** 0.244*** 0.732	-0.030* 0.517*** 0.110 0.533	-0.149 0.270 1.246 0.598
Finland	-0.135** 0.037 0.164 0.306	-0.010 0.745 0.693 0.449	-0.048** 0.278** 0.056 0.410	-0.107** 0.285* 0.153 0.484	-0.118*** 0.464*** 0.029 0.401	-0.116*** 0.375*** 0.301*** 0.600
Netherlands	-0.152*** 0.005 0.555*** 0.580	-0.091** 0.349*** 0.123 0.462	-0.016 0.124 0.134 0.395	-0.083** 0.338*** 0.195* 0.582	-0.064* 0.684*** -0.069 0.446	-0.083** 0.300*** 0.405*** 0.508
Sweden	-0.063 0.092 0.590 0.246	-0.017 -1.078 1.190 0.420	-0.002 -8.456 0.027 0.727	-0.045* 0.365 0.604** 0.612	-0.034* 0.268 0.263 0.482	-0.038* 0.410* 0.711** 0.634
UK	-0.079* 0.023 0.050 0.195	-0.053*** 0.470*** 0.063 0.547	-0.035*** 0.352*** 0.260 0.730	-0.013 -0.332 0.629 0.742	-0.067*** 0.556*** 0.089 0.656	-0.055*** 0.329*** 0.267* 0.700
RESULT (no. of significant price determinants in sector)	**1 Domestic 1 US**	**2 Domestic 1 US**	**2 Domestic 0 US**	**3 Domestic 3 US**	**4 Domestic 0 US**	**4 Domestic 5 US**

[1] Using US$ exchange rates and imposing PPP. * Significant at 10%, ** Significant at 5%, *** Significant at 1% level

Table 2.5.1 Modelling the domestic output price - with German price representing the foreign price[2] (DM Exchange Rate: PPP imposed)

-Adjustment speed λ -Domestic cost -Foreign price -Fit: Adjusted R^2	Chemicals	Food, Beverages and Tobacco	Non-metallic Mineral Products	Paper and Paper Products	Wood and Wood Products	Basic Metals
Denmark	-0.175*** 0.007 0.389 0.454	-0.122*** -0.134* 1.003*** 0.429	-0.234*** 0.513*** 0.139 0.211	-0.113*** 0.258*** 0.636*** 0.562	-0.100*** 0.458*** 0.358*** 0.420	-0.156*** 0.079* 0.866*** 0.500
Germany	..	..	..	..	..	..
Finland	-0.154*** 0.112 0.210 0.670	-0.003 0.327 -6.157 0.479	-0.315*** 0.419*** 0.053** 0.227	-0.063*** 0.197 0.501 0.555	-0.069*** 0.365** 0.186 0.389	-0.136*** 0.194** 0.516*** 0.643
Netherlands	-0.034 1.610 -1.874 0.758	-0.098*** 0.847* -1.333 0.481	-0.177*** 0.406*** 0.412*** 0.178	-0.031 0.624 0.320 0.833	-0.093** 0.703*** 0.065 0.461	-0.139*** 0.146** 0.665*** 0.605
Sweden	-0.071* 0.082 1.048* 0.579	+0.011 3.063 -1.113 0.553	-0.176* 0.716*** 0.018 0.257	-0.079*** -0.013 1.036*** 0.667	-0.029** -0.342 0.806* 0.587	-0.124*** 0.047 0.942*** 0.830
UK	-0.113** -0.136 0.436* 0.540	-0.056*** 0.306*** 0.376** 0.628	-0.167** 0.518*** -0.000 0.216	-0.020** -0.167 0.670** 0.774	-0.049*** 0.324*** 0.274*** 0.760	-0.115*** 0.229*** 0.476*** 0.830
RESULT (no. of significant price determinants in sector)	**0 Domestic 2 German**	**3 Domestic 2 German**	**5 Domestic 2 German**	**1 Domestic 3 German**	**4 Domestic 3 German**	**4 Domestic 5 German**

[2] Using DM exchange rates and imposing PPP. * Significant at 10%, ** Significant at 5%, *** Significant at 1% level

2.5.3 Results by sector

As described, a set of four figures is given for each sector in each country, namely, λ which is the speed of price adjustment; the second indicates the influence of domestic cost (domestic wage rates) in the long run; the third indicates the influence of the 'foreign' output price in the long run, which in Table 2.5.1a is the US price and in Table 2.5.1b is the German price, acting in the manner of an 'EU price'. The fourth figure is the measure of fit.

Chemicals

For this sector, there is a better fit generally when the German as opposed to the US price is used to represent the foreign price. The long-run relationship, as measured by **λ,** was found to be significant for most countries with a few exceptions[1]. Turning to the strength of domestic versus foreign influences on the output price, results in Table 2.5.1a are somewhat mixed. The US price is found to influence chemicals output prices only in the Netherlands (quite strongly). In Germany in particular the results suggest that domestic costs have a significant influence. In Table 2.5.1b, where the German price was used as the potential foreign price determinant, Sweden and the UK are found to respond to this price, having not responded to the US price. Domestic costs are not significant determinants in any country when the German price represents the external price. The speed of adjustment is generally higher where the German as opposed to US price plays the role of external price. This sector could be vulnerable under an environmental tax regime in certain countries, especially in the Netherlands, which showed clear signs of being a price taker of the US price. By contrast, the influence of the German price in Sweden and in the UK suggests that the sector is a price taker on the 'EU market'. However if ETR were applied in an EU-wide manner, it would affect EU 'competing' countries in a consistent manner, removing fears of vulnerability. Results for this sector therefore show that the world price is a constraint in only some places.

Food, Beverages and Tobacco

For this sector the fit is somewhat improved when the foreign price is represented by the German as opposed to the US price. The adjustment coefficient is also marginally stronger and more significant, though Germany, Finland and Sweden are poorly modelled by this long-run relationship in general, regardless of the foreign price used. Turning to what determines the domestic output price, only results for Denmark suggest an influence from the US price, though with only 10% significance, while the UK (quite strongly) and the Netherlands indicate that domestic costs dominate. In Table 2.5.1b the German price can be viewed as a proxy for the effect of the Common Agricultural Policy. We find here that output prices in Denmark and the UK respond to this 'EU price', having not responded to the US price in Table a. The UK and the Netherlands show domestic costs exerting a strong influence on their price-setting regimes.[2] There does not appear to be widespread vulnerability to environmental tax reform therefore if applied at EU level.

Non-metallic Mineral Products

This sector is not highly traded and the US price, as the foreign price, is not significant in explaining movements in the sector's output price. In the UK in particular the model shows domestic costs as a determinant. If the sector responds to any foreign price, it is likely to respond to the European price, probably owing to the bulky nature of the product and its high weight-to-value ratio. In Table b, however, where the external price is represented by the German price, the outcome is a worse fit and the German price is only significant in the Netherlands and to a minor extent in Finland. Domestic costs on the other hand significantly determine a substantial portion of this sector's output price in all countries investigated. To the extent that the external price is at all significant, the fact of it being the German price indicates that a carbon-energy tax applied EU-wide would not create significant competitive disadvantage, given that the rest of the EU would face a similar tax.

Paper and Paper Products

In this sector we find that a better fit is shown when the foreign price is represented by the German price, rather than by the US price. Nevertheless, Sweden and Germany, and the Netherlands to a lesser extent,

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[1] The long-run relationship only holds for Sweden when the US price is used. For the Netherlands it applies only when the US price is used.

[2] The UK is an example of the third type of outcome mentioned above, where both domestic costs and the German prices are significant and the sector is both price taker with respect to European prices, and price setter.

show a significant impact from the US price, an impact which is large in the case of Sweden. In Germany's case, domestic costs also have a significant but larger impact, a pattern also prevailing in the Netherlands. Taking the German price as the foreign price[3] in Table 2.5.1b, we find here that the external price dominates the effect of domestic cost, with the exception of the Netherlands' case. This is particularly so in Denmark, the UK and Sweden and provides strong evidence that this sector is highly traded and could be vulnerable to energy taxes in the sense that it would not be able to pass on this increase in its cost of production. This sector is generally shown to be a price taker and can be classified as being particularly vulnerable to such policy change in the absence of mitigation policies or technical adjustments. Such disadvanatages for competitiveness could be reduced if the same cost increase due to ETR applied across all of the EU.

Wood and Wood Products
The findings for wood and wood products show that a better fit is generally obtained using the German rather than the US price. In all cases using the German price the adjustment coefficient is significant at least at the 5% level. The results for Sweden are anomalous. For the other countries examined the coefficient on domestic costs is highly significant and greater in magnitude than that on the foreign currency price. This suggests a significant degree of market power on the part of firms and an ability to absorb at least some of the incidence of any environmental taxes. The fact that it is the German price rather than the US which provides better explanatory power in the equations suggests that where an environmental tax regime (or emissions trading regime with auctioning) is introduced on an EU-wide basis there would be little effect on the competitiveness of domestic output, with all firms supplying the EU market being affected in a consistent manner.

Basic Metals
In the basic metals sector the US price has a strong and significant influence on output prices except in the case of Germany. An even stronger external price effect is found when using the German price as the external price, but this sector is evidently a price taker on world markets as results indicate that this sector's pricing is the most responsive to external prices. The German price is also a highly significant determinant of the output price and far outweighs the influence of domestic costs, which are of lesser significance and in fact insignificant in the case of Sweden. The exceptions, where domestic costs are significant at the 1% level is the 'insular' country, the UK, though the magnitude of the effect of domestic costs is still smaller than that of the German price. The adjustment coefficient suggests a relatively strong and significant stable long-run pattern of response across all the countries studied.

All sectors
The high level of aggregation chosen for the industrial sectors was dictated by the availability of comparable data. At this high level of aggregation there are obviously significant differences in the composition of each sector across countries. For small countries there is a higher probability that the sector may be dominated by a limited number of more specialised firms. This means that the results for different sectors from different countries are not always comparable and that the factors determining price setting may differ. However, what is important in this analysis is the fairly consistent pattern that emerges where the same sector across a number of countries considered is either a price taker or a price setter.

In this paper we assume that in the long run the effects of a change in foreign prices in foreign currency terms are the same as the effects of a change in the bilateral exchange rate. Thus a one per cent rise in the foreign currency price for the output of the non-metallic minerals products sector will in the long run have the same effect on domestic prices as a one percentage point rise in the bilateral exchange rate.

2.5.4 Conclusions on price-setting power

This analysis of price setting by the selected sectors across ETR countries produced plausible results with good explanatory power. Use of the German price as a proxy for the external price generally fitted the data better than when the US price was used. The exception to this was the non-metallic mineral products sector, where the foreign (German) price was only significant in the Netherlands and to a very small extent in

[3] With the high level of Swedish and Finnish paper and pulp products on the world market, Sweden's sectoral price is accordingly strongly representative of the world price for paper and paper products.

Finland. Use of the German price was in general also more consistent with a stable long-run price-setting relationship.

These time-series regression results are now used to produce a suggested ranking of the selected sectors according to decreasing significance and influence of the external price. Starting with the most vulnerable, this ranking indicates corresponding increasing market power in the following order:

1. Basic metals
2. Paper and paper products
3. Wood and wood products
4. Chemicals
5. Food, beverages and tobacco, and
6. Non-metallic mineral products.

Basic metals were very susceptible to international trading conditions and would be significantly affected by an energy or carbon tax (in the absence of mitigating or other measures). The sector could be placed at a cost disadvantage compared with its trading partners. Non-metallic mineral products, on the other hand, responded very closely to domestic costs (wage costs in this analysis) and appeared to be relatively insulated from international trading conditions. Relative to the other sectors, the non-metallic mineral products sector would be best placed to absorb a cost increase on foot of carbon or energy taxes, by passing on the tax to its (mostly domestic) customers in the form of higher product prices if, that is, there were no other options such as making worthwhile alterations to its technology.

While we have established a hierarchy of sectors in terms of their potential vulnerability to environmental tax reform this hierarchy only holds within a reasonable range of tax rates. It is always possible that in the event of a massive rise in tax rates affecting firms' energy prices, firms that were previously price setters, might become price takers. However, it would take a very large rise in tax rates to bring this about.

2.6 Foreign Direct Investment and ETR

2.6.1 Introduction

Attention now turns to the effects of Environmental Tax Reform (ETR) on foreign direct investment (FDI). The question to be investigated is: does the introduction of the tax part of ETR, the carbon or energy tax for example, deter potential foreign investors? At the extreme, does the tax encourage existing companies to threaten exit or actually to relocate? The question amounts to asking whether carbon/energy taxes redirect carbon emissions to countries that do not have similar carbon/energy taxes or quotas. In other words, is there carbon leakage?

The question is closely related to the issue of "pollution havens", which has been the subject of popular and contentious debate. Profit maximising investors seek low input costs. Putting this in its proper context, in addition to using labour and capital, polluting sectors use the dispersal services or assimilative capacity of the environment. Other things being equal, charges such as carbon/energy taxes represent an extra "price" imposed on assimilative capacity which investors will take into account when deciding where to locate.

The issue is investigated here by means of a literature survey. This section summarises the literature and reports on some statistical analyses and case studies that investigate carbon leakage and pollution haven effects.

It must be stressed that to date no study that addresses our precise question, the effects of ETR, has come to hand. The issue is perforce investigated from several indirect angles and even then the implications for ETR proper will be seen to be uncertain. This is because the studies to hand investigate the effects of measures such as regulations and standards. In general empirical research into the pollution haven hypothesis asks: do polluting industries go to the areas with low regulatory standards?

Looking at the effects of regulatory stringency can be viewed as only a rough proxy for looking at the effects of environmental taxes. Though ETR and regulations both raise industry's cost of polluting, they are significantly different in detail. ETR allows the firm flexibility, it involves less bureaucracy and the recycling of revenue can mean that the firm incurs less net cost, or may end up in profit from the introduction of ETR. There is little or no research on the effects of environmental taxes or of ETR *per se* on FDI but it is nevertheless instructive to check the economic literature on the related effects of environmental regulations and to outline developments in the pollution haven debate.

It is worth noting here the possibility of imposing carbon taxes on the one hand and, on the other hand, of exempting or reducing the carbon tax in order to mitigate the effect on vulnerable firms – which is the subject of Work Package 5. Such exemptions have their counterpart under a regulatory regime, where they are sometimes called “regulatory chill”. This is the situation in which regulations are softened or not increased, or simply not enforced, in order to placate investing companies or avert exit threats. If such exemptions are pursued in retaliatory fashion by countries competing for investment, this can result in a “race to the bottom” or, less dramatically, in mediocre performance in adopting environmental reform, otherwise described as being “stuck in the mud” (Zarsky, 1999). In addition to providing picturesque phrases, this heated debate’s concerns about industrial location and environmental degradation has produced a wide-ranging literature and pertinent surveys and critiques, which are drawn on here (Jenkins, 1998; Fortanier and Maher, 2001; Brunnermeier and Levinson, 2004).

2.6.2 The pollution haven hypothesis

A brief description of the evolution of the pollution haven hypothesis runs as follows.

- Between 1960 and 1995 the share of pollution intensive industries declined in OECD countries and increased in Latin America and Asia. This led to speculation that changes in income, regulation and energy prices were the cause (Mani and Wheeler, 1998). A consensus arose from empirical findings however that regulatory differences did not matter, except with respect to highly polluting industries.
- Forming an important context to the debate was the finding of an environmental Kuznetz curve. While increases in GDP may be associated with worsening environmental conditions in very poor countries, economic growth appears to benefit air and water quality once some critical level of income has been reached (Grossman and Krueger, 1994).
- This inverted U-shaped relationship for environmental quality suggests that there is an induced policy response as citizens get richer. Another possibility is that structural shifts or other causes may be at work.
- Available econometric evidence did not in general support the contention that industry was attracted to low environmental standards. Grossman and Krueger (1993) using cross-section data on US imports from Mexico found, if anything, more rather than less imports in ‘low pollution’ industries. These were modest but counter-intuitive results. Studies concluded in general that environmental regulations have little effect on location decisions (Jaffe *et al,* 1995) and that the pollution haven hypothesis could not be proven.
- Environmental costs were thus considered to be merely one of a broad number of factors determining location, including wage costs, skill formation, quality of infrastructure, access to inputs, income levels, openness and size and growth of potential markets in which to sell.
- The costs of adhering to environmental regulations are typically a small part, on average 2 to 3 per cent, of total production costs of most firms (Adams, 1997, OECD, 1998, UNEP, 2000).
- Rather than seeking lax environmental enforcement, multi-national enterprises would generally prefer consistent enforcement (OECD, 1997).
- Foreign investment, primarily from the US or Japan appears to be attracted to the services or the signals about the local investment environment that stringency provides. The inverse correlation between national environmental performance and perceived corruption (TI, 2000) may also mean that investment is attracted to countries with environmental regulatory stringency.
- Source-country shareholders may not want to be accused of allowing lower technological standards to be used abroad.

Despite voluminous research, until the mid-nineties econometric evidence to back up the pollution haven hypothesis eluded researchers. Alongside the above reasoning, the strong growth in FDI in developing countries was considered to reflect primarily the low cost of labour and the abundance of resources. It was thought that companies were unlikely to use a lower grade or dirtier technology than that which they employed in developed countries. They would tend to invest in state-of-the-art technologies regardless of location, preferring to reap the scale benefits of standardisation in environmental, health and safety management systems, rather than simply exploit weaknesses in local legislation. They would also respond to pressure from the public at large and civil society. The dispersion of FDI and ensuing trade could therefore raise the environmental standard of production worldwide, it was argued.

The popular debate on the pollution haven hypothesis became more polarised with the demonstrations at the World Trade Organisation (WTO) meetings in Seattle and Genoa. At the same time the research consensus that regulatory differences do not matter altered somewhat as more thorough studies were embarked upon.

Recent research papers have used time-series panels rather than cross-section data. These studies can control for unobserved attributes that are correlated with regulatory stringency or economic strength. Another issue hinted in the above discussion of environmental regulations becoming stuck is that regulatory stringency may itself be endogenous. Location decisions and trade may respond to environmental regulations but these regulations may in turn react to location decisions and trade. Recent modelling work has attempted to separate the effect of regulatory stringency, without the confounding effect of trade on stringency. As a result of these changes in approach recent papers have in fact found a statistically significant effect of environmental regulations on trade and investment. Brunnermeier and Levinson, *op cit,* cite studies supporting the pollution haven hypothesis, if only to a small degree, by Bartik (1989), Levinson (1996), van Beers and van den Bergh (1997), Osang and Nandy (2000), List and Co (2000), Ederington and Minier (2003) and Levinson and Taylor (2004). Compelling evidence is also found by Waldkirch and Gopinath (2004).

Empirical investigations of the pollution haven issue typically fit models of the form:

$$Y_i = \alpha F_i + \beta R_i + \gamma T_i + \varepsilon_i$$

where the dependent variable Y is some measure of economic activity. Economic activity can be represented by such items as inbound or outbound foreign direct investment, new plant openings, employment, pollution, net exports or net imports. These can variously represent location choice, output effects or input effects. Regressor F represents factor endowments, such as human and physical capital and infrastructure, R is a measure of stringency of environmental regulations, T is trade barriers and ε is a random error term. The pollution haven effect would be captured if $\partial Y/\partial R < 0$, that is, if the economic activity is negatively affected by increased regulatory stringency.

There are several estimation issues that have come to dominate recent investigations, the main ones being:

The use of panel data or cross-section data. The later studies use panel data, over a period of six to seventeen years. The counter-intuitive findings of the early studies using cross-section data could be explained by unobserved industry or country characteristics that are likely to be correlated with the propensity to impose strict regulations or the propensity to manufacture and export polluting goods. In a cross-section model omission of these variables risks giving misleading results. Panel data can control for characteristics and may overcome these problems.

Endogeneity of environmental policy: This can invalidate the model as it stands. For example, if greater economic activity leads to higher income, which in turn leads to demands for higher environmental quality, then environmental stringency could be a function of dependent variables trade or investment. The econometric solution is to employ instrumental variables and apply two-stage least squares. When endogeneity is accounted for, Levinson and Taylor (2004) among others found that the U.S. industries that experienced the largest increases in pollution abatement costs (a proxy for regulatory stringency) during the 1970s and 1980s also experienced the largest relative increase in net imports.

Measurement of environmental stringency: This is a source of difficulty that probably surpasses the problems associated with the data on foreign direct investment. Proxies are invented to measure stringency. These include environmental indices, which can suffer from being objective. Ratios of emissions to output can be used, based on U.S. levels as developed in the World Bank's industrial pollution projection system (IPPS). Their application to non-U.S. sectors is to assume common technologies, regulations and enforcement. Another measure of regulatory stringency is pollution abatement costs, which can comprise pollution abatement capital expenditures or operating costs. Keller and Levinson (2002) find robust evidence that pollution abatement costs, when adjusted for state industrial composition, have a modest deterrent effect on the value and count of new foreign investment projects. A doubling of their abatement cost index is associated with a less than 10 per cent decrease in foreign direct investment. Another proxy measure can be constructed from actual pollution levels, such as ambient air quality, which have the benefit of objective measurement as do emissions data to a lesser extent.

A study of the extent to which changing environmental standards have altered patterns of international investment

The study “Pollution abatement costs and foreign direct inflows to U.S. states” was undertaken by Keller and Levinson (2002) and published in the *Review of Economics and Statistics.* Rather than compare regulations in different countries, the authors look instead at inward foreign direct investment to the US. There are advantages in using US data and different levels of regulatory stringency apply between US states. The authors use a 17 year panel for their model of the broad form:

$$\text{Ln}\,(FDI_{st}) = \beta \ln (S^{*}_{st}) + \gamma X_{st} + \delta_t + d_s + \varepsilon_{st}$$

where FDI_{st} is foreign direct investment in state s during year t, S^{*} is a carefully constructed index of the relative stringency of environmental regulations in each state in each year, and X_{st} is a set of other state characteristics that may affect inward investment, such as market proximity, taxes, energy costs, land prices, wages, unionisation and so forth. Year dummies are given by δ_t, and unobservable state characteristics that would otherwise impart an omitted variable bias are represented by d_s which are state fixed effects. ε_{st} is an error term.

The index of regulatory stringency S^{*} measures state pollution abatement costs using the PACE data but, importantly, it is adjusted using each state’s industrial composition, at the level of 2-digit SIC codes. The stringency of environmental legislation differs much more across countries of the world than across US states, however the variation in other regressors is also greater across countries than across states. Thus, claim the authors, the analysis does not necessarily underestimate the sensitivity of FDI location to environmental stringency at international level.

From their model they obtain an elasticity (β) of FDI with respect to regulatory stringency of –0.079 for all manufacturing industry (statistically significant at 10%) and –0.198 for the chemical sector (statistically significant at 5%) which is used as an example of a pollution-intensive industry.

In sum, the authors find ‘robust evidence’ that pollution abatement costs have had a moderate deterrent effect on foreign direct investment, which is somewhat stronger in the case of the representative pollution-intensive sector.

Variants that test specifically whether competition for mobile capital induces countries to set suboptimal standards have not been applied. Several articles have tested for and found strategic behaviour in the US.

In sum, empirical work investigating whether economic activity responds to regional regulatory differences has arrived at differing conclusions. These tended initially to point to a counter-intuitive, modest, attractive effect of regulatory stringency. However several recent studies that use panel data and control for endogeneity find statistically significant though small pollution haven effects. It does not appear to matter whether the studies look across countries, industries, states or counties, or whether they examine plant location, investment, or international trade patterns.

Such a finding is not inconsistent with studies of international capital flows and company tax in general. In their meta-analysis, which is a synthesis of research results from the literature on taxation and FDI, de Mooij and Ederveen (2007) find a 2% to 3.9 % increase in FDI for a one point change in the tax rate. That is, a tax rate decline from, say 30 per cent to 29 per cent.

A study of what makes an exit threat credible
If a firm's exit threat is credible, the more likely it is to be able to exert influence on legislative and fiscal provisions. Four relevant characteristics have been highlighted by Massey (1999). These are :

- *The size of the fixed investment* - the larger the required fixed investment, the more costly relocation would be and thus the less credible the threat to exit.

- *Absence of product differentiation* - if the firm's products are traded and indistinguishable from those of another firm, extra costs incurred by environmental laws or taxes cannot be passed on in the form of a premium that consumers can recognise as environmental. The firms are price-takers and their exit threat could be credible.

- *High abatement costs* - if regulated abatement or a tax constitutes a high share of expenses in general then the firm can credibly claim to be vulnerable unless, that is, other characteristics give them price-setting power in the manner outlined in the previous section, or technological options.

- *Dependence on exhaustible resource* – As the resources near depletion the exit threat becomes more credible but then the loss is smaller.

Analyses of pollution intensive sectors

- It is possible that firms in the more pollution intensive industries, such as chemicals, metallurgy, and pulp and paper, and industries in the resource extraction sector gravitate to pollution havens and there could be a tendency for environmental policy to acquiesce. This appears to have been experienced in both developing and industrialised countries (OECD, 2002).
- The pattern of investment in China, however, in pulp and paper and other polluting industries suggests that foreign investment is attracted to provinces with more stringent regulations, the opposite of the pollution haven hypothesis (Dean *et al*, 2004). Chinese-sourced equity, by contrast, gravitates to states with low standards.
- In the steel industry, an OECD-wide carbon tax of $ 25 per tonne of CO_2 <u>without</u> revenue recycling, would reduce OECD steel production significantly, by an estimated 9 per cent, the reduction being concentrated at the heavily polluting end of the sector. Relocation to non-OECD countries is estimated to raise their production by almost 5 percent, implying a world fall in steel production of 2 per cent and, despite higher emission intensities in non-OECD countries, global emissions from the sector would decline by 4.6 per cent due to cleaner processes in the OECD area. If revenues were recycled back to the steel industry as an output subsidy, OECD production would restructure towards cleaner processes and the reduction would be less than 1 per cent and global emissions reductions in the sector would reduce from 4.6 per cent to 3 per cent (Maestad, 2003).

The implications of the re-instatement of the pollution haven hypothesis (though its effects may be very minor overall) are not that regulations or ETR should be scaled down, as if their costs outweighed the benefits overall. Rather, efforts should be made to induce host countries, via trade or EU accession agreements, to strengthen their environmental policies. The results highlight the logic of co-ordinated global environmental rules (Waldkirch and Gopinath *op. cit.*). This would not necessarily mean uniform pollution standards because of differences in the capacity to assimilate certain pollutants. It may be efficient for polluting industries to move to regions that put less emphasis on environmental quality provided that the regions do so for appropriate reasons, meaning that there is no market failure, political failure or redistributional concern involved and there are no global or trans-boundary externalities (Bhagwati, 1993). Global warming is however a case of global externalities that suggests uniform world rates of tax/subsidy on emissions/sequestration, given that a unit of carbon dioxide tends to have a similar global warming effect regardless of location (Parry, 2003).

Another obvious possible response that gives ETR the advantage over regulations is to avert industrial relocation by using the revenues to implement mitigation measures. This is the subject of Work Package 5.

2.6.3 Views of development and industry agencies

The views of development agencies and business representatives were sought, in order to obtain first hand observations of how ETR influenced the location decisions of foreign direct investment and whether relocation had been prompted. The organisations contacted were not representative, but their responses provide some insights. They were asked two main questions:

(1) Has the introduction of carbon/energy taxes or eco-taxes influenced Foreign Direct Investment in your country?
(2) Are there instances that can be cited?

Their responses were as follows:

A response for East Germany indicated that there is a certain effect. Companies know that Germany is a high-cost and high-tax location, but not only because of eco-taxes. For some companies, Germany is no longer on their short-list and they search for 'low-cost' countries.

On the other hand there are a lot of initiatives and incentives offered by the German government to reduce the cost and tax burden for companies, like the "Energie-Einspeise Gesetz" which offers many incentives to companies engaged in new energy, production technologies, photo-voltaics *et cetera*, in order to reduce the capital burden.

For some companies investigating conditions in the UK, the Climate Change Levy is considered to be a discouraging factor but then all states have some sort of climate change imposition due to the Kyoto Protocol. Although there may be a push factor for some firms to leave, there is little pull factor in other states to encourage them to relocate. Meanwhile the UK's targets in respect of the renewable energy strategy are themselves an attraction to overseas investors with this sort of technology.

There are apparently no instances to date of relocation due to the Climate Change Levy. Some firms in the energy-intensive sectors did relocate to Eastern Europe but this was not due to the Climate Change Levy, as other factors such as labour costs come into play.

With respect to the Netherlands, it is instructive that their Foreign Investment Agency highlights the advantages of the location for the chemical industry. Features that it draws attention to (as cited in a survey of U.S. chemical companies) are:

> "Transparent and consistent environmental policies and a quick permitting process", stating that the government's emphasis is on reducing and simplifying environmental rules and regulations.

Other indications on the issue are to be found in some recent debates. For example, in the run-up to the introduction of ETR in the form of the Climate Change Levy in the UK, virulent national debates occurred between the authorities and the sectors most at risk (though not apparently from those who are gaining). Sectors citing vulnerability to competition included the steel industry, aluminium, fertilisers, salt, horticulture, and cement, the last reporting that it was acquiring cement plants in Greece and Poland.

Recent discussions on the proposals in REACH (Regulation on the registration, evaluation and authorisation of chemicals) are pertinent to the issue. There is concern that the chemical industry could transfer some operations elsewhere. A recent report by consultancy KPMG examined the four sectors, automotives, flexible packaging, inorganics and electronics. The report however does not indicate that industries will relocate because of REACH. In the case of the automotive industry it considered that proximity to customers and heavy investment in the EU were the main reasons for companies staying where they are.

In the literature review by Brunnermeier and Levinson (*op. cit.*), there is a summary of surveys undertaken over the last two decades that try to understand industry location decisions. Two surveys are worth noting. UNCTAD (1993) sampled 169 corporations with sales exceeding $1 billion (1990) most of which claimed that corporations' environmental, health, and safety practices overseas were determined by home country regulations. The second example is by the U.S. General Accounting Office which surveyed 2,675 wood furniture manufacturers in Los Angeles in 1988-1990. In the region of 1 per cent relocated at least some part of their operations to Mexico, citing labour costs and pollution control costs as significant factors affecting their decisions. Brunnemeier and Levinson are of the view that the results of these surveys are inconclusive.

2.6.4 Conclusions on FDI

The debate continues but the main points that have emerged to date provide helpful context.

- No studies have been identified that specifically investigated the issue of concern here, that is, the effects of ETR, in Europe or elsewhere, on location decisions.
- Studies of the relocation effects of environmental regulatory stringency have been undertaken and these were examined for want of more pertinent analyses.
- There is a large literature investigating the hypothesis that firms relocate to areas with less stringent regulations, that is, to so-called 'pollution havens'.
- Discussions with development agencies and industry associations give mixed indications but flag important issues, in particular the roles of labour costs and taxation in general, in the location decision. Regulations regarding health, safety and the environment, environmental policies that are transparent and consistent and a quick permitting process also feature.
- Early empirical investigations of the pollution haven hypothesis based on cross-section data found scant evidence for the hypothesis. Some counter-intuitive indications emerged that the reverse could be the case: that compliance costs or abatement costs could have a positive effect on net exports. This tended to be explained by the fact that environmental compliance costs are for the most part quite small and by the greater importance attached to labour costs, local markets, and natural resources where relevant.
- Recent studies that use more extensive records and panel data are able to control for econometric problems (unobserved heterogeneity and endogeneity, in particular) and these typically find some evidence of a minor pollution haven effect due to environmental regulations. The other attracting factors are market size and labour costs.
- To discourage the 'race to the bottom' in face of threats of undercutting by countries that lower standards to compete for investment, host countries could be induced to strengthen their environmental policies via trade agreements that promoted appropriate global safeguards and taxes.
- In sum, the mixed evidence for the pollution haven hypothesis including the recent work that supports the hypothesis, does not necessarily apply to environmental tax reform. In particular, the manner of ETR implementation can help to avert industrial relocation by careful targeting of the recycled revenues to mitigate the effects of the tax side of the ETR.

2.7 Summary and conclusions

This work package has looked at the structure and market in which manufacturing sectors have to operate and compete. Various aspects of structure and market have been investigated with a view to assessing the vulnerability of manufacturing sectors in a period corresponding closely that when environmental tax reform was being introduced.

2.7.1 Potentially vulnerable sectors

Screening of all manufacturing sectors at the NACE 2-digit level was undertaken in order to identify sectors that might be vulnerable. For each sector, calculations were undertaken of energy expenditure shares (of value added, gross output and operating surplus); labour's share of value added; exports as a share of total output; imports as a share of supply on the domestic market, and of the shares of exports going to EU and non-EU destinations. Using each of these various measures the sectors could be ranked and allocated to categories of high, medium and low vulnerability. A key measure is energy intensity as this determines the amount of tax due under ETR.

Representation of sectors with low labour intensity was needed as these could be vulnerable under ETR where revenues were recycled to reduce labour taxes. They could find themselves "under compensated". After consultation with project partners and taking geographic relevance into account, seven sectors were selected for more detailed analysis here and in the next Work Package. These are as follows:

Table 2.7.1 Seven potentially vulnerable sectors selected for further analysis by the COMETR study

	NACE code	Characteristics: intensity			
		Energy	**Labour**	**Export**	**Import**
Food and beverages	15	high	low	low	low
Pulp, paper and board	21	high	medium	low	low
Wood and wood products	20	medium	low	low	low
Basic chemicals excl. pharmaceuticals	24 less 24.4	high	low	high	high
Pharmaceuticals	24.4	low	low	high	high
Non-metallic mineral products	26	high	medium	low	low
Basic metals	27	high	high	medium	medium

Source: Table 2.2.1, see notes to table. Slight differences in selected vulnerable sectors within COMETR are due to data availability in different data sources.

These sectors were studied in detail in this Work Package except where source data on Wood and wood products (20) and Pulp, paper and paperboard (21) are combined owing to data constraints.

2.7.2 Observations on sectors

Proceeding to look at the details it was seen that within each vulnerable sector there is much variation in unit energy costs between countries. In Basic metals, an extreme example, unit energy costs in West Germany in 1998 (as a share of gross value added) came to 56.3 per cent compared to 8.5 per cent in the UK. There appears to be more consistency however within countries. A country that has high unit energy costs in one sector tends to have high unit energy costs in many other sectors as well, Germany and the Netherlands are examples. Denmark and then the UK have consistently lower unit energy costs.

As a precursor of analyses to come, it was attempted to compare pre- and post-ETR situations. A comparison was also attempted between ETR and non-ETR countries, where the non-ETR countries used were Belgium, Spain, France, France, Italy, Austria, and Portugal. Because ETR was introduced quite late (1999 and 2001 in Germany and the UK, respectively) and quite early in Sweden, in 1991, the span of data was not unsatisfactory and in any event the pattern is mixed. Unit energy costs in the selected sectors averaged over 1993 to 2002 were higher for the non-ETR countries than in the ETR countries in general. The change in physical energy consumption over 1990 to 2003, comparing the average for ETR countries with the average for non-ETR countries, shows a definite relative decline for ETR countries in three vulnerable sectors, namely, Chemicals, Mineral Products and Food, drink and tobacco. A slower rise rather than an actual decline, was seen for Paper and pulp and a very marginally higher, though still small, rise for Iron and steel.[4] Data constraints unfortunately meant that the figures of energy consumption are not expressed per unit of gross value added so that scale effects are not taken out.

It was found that Sweden tended to have the highest unit labour costs across the chosen sectors, which could be important under ETR depending on how revenue is recycled, as Sweden does not have the highest labour intensity when it comes to all manufacturing. The UK tended to have the highest labour intensity across the identified vulnerable sectors, with the exception of Food, beverages and tobacco. The Wood and paper sector and the Non-metallic minerals sector were classified as having the highest unit labour costs, while Basic metals and in particular Food, beverages and tobacco had the lowest unit labour costs (measured against

[4] This points to the desirability of constructing a two-by-two table of unit energy costs and of average emissions intensity for each sector, if data permitted. Each sector would have a table giving the ETR average and non-ETR average, broken down in turn by pre-ETR average and post ETR average. The non-ETR countries would serve the purpose of a "control group".

gross value-added). The last two sectors tended consistently to have lower labour intensity rates than the total of all manufacturing in each country.

An indication of international competitiveness can also be gained by the export and import intensities of the sectors identified. As expected, our analysis showed strong, and growing, export intensities for Wood and wood products from 1970 from Finland and Sweden. Sweden also saw a very large increase in export intensity of Pharmaceuticals. Denmark saw a large rise in export intensity in Basic chemicals, with the UK also rising but with a decline in the Netherlands. Pharmaceuticals are heavily traded, in the cases of Sweden, and Basic chemicals in the case of Denmark. Non-metallic mineral products has low-ish trade intensity, though rising in the cases of Sweden, Denmark and Finland; Basic metals are exceptionally highly traded in the cases of Sweden and Finland, and growing. Food and beverages are rather low in export intensity with Denmark and the Netherlands at the higher end of the countries studied.

A very high proportion of trade takes place within the EU for the sectors of interest. The UK generally trades less with the EU than do its continental partners, while Scandinavian partners have very high trade rates between themselves that are also captured as intra-EU trade.

Non-metallic mineral products are traded least of all the sectors studied, barring Food, beverages and tobacco, which might be explained by its bulky nature and high weight-to-value ratios. The Food, Beverages and Tobacco sector is not highly traded either except in the case of Denmark, which is highly dependent on exports from this sector, and the Netherlands.

2.7.3 Market power

The effects of competition hinge on whether or not the selected sectors can pass on increases in costs, such as the cost increases due to the introduction of carbon or energy taxes. In other words do they have market power, or are they price takers who have to be able to match the world price or else go out of business? Sectors that fall into the latter category can be particularly vulnerable to an ETR policy change unless the revenue recycling mitigates the damage or technical options are favourable.

Price determination was investigated in each of the selected sectors for which data were available. The influence of domestic costs as against world prices was tested. This was undertaken by examining the long-run structural relationship between domestic output prices, on the one hand, and foreign or world prices and domestic wage costs, on the other. If domestic wage costs are significant determinants of the sector's output price then this indicates that the sector can pass on environmental taxes. It is a price setter and therefore has market power. If the world price determines the sector's price then it is a price taker. It cannot pass on cost increases and could be vulnerable. It could be adversely affected if a new tax were introduced that increased its cost base because it would be unable increase its market return. Such an adverse effect could be overcome if domestic wage costs could be reduced in parallel, as would be the case if revenue recycling lowered social insurance contributions by employers correspondingly, thereby maintaining cost neutrality. There is also the possibility of intermediate positions between the two determinants, that is, price-taking of prices set in the international market plus mark-up pricing.

Using quarterly data from 1975 to 2004 inclusive, the model performed overall well statistically and gave plausible results. The general ranking of sectors according to the model's estimation of the strength of foreign versus domestic price determination was made. This ranking shows the vulnerability to competition, starting with the most vulnerable sector, as follows:

Basic metals
Paper and paper products
Wood and wood products
Chemicals
Food, beverages and tobacco
Non-metallic mineral products.

The econometric evidence suggests that in the case of Basic metals the foreign price generally has the dominant effect, in terms of significance and size of coefficient. This sector is a price-taker and this applies to all the ETR countries under review except Germany. The US price was a less strong determinant than was the German price. For the selected sector at the other end of the range of vulnerability, Non-metallic mineral products, the domestic cost is the dominant determinant meaning that the sector is generally a price-setter. An exception is the Netherlands where the foreign (German) price and domestic costs have about equal importance.

A point to note is the fact that where the foreign price mattered, the US price was less significant or important, in general, than the German price. The implication of this finding is that EU-prices are be a stronger constraint on firms. Therefore a EU-wide application of ETR, that had a similar effect on the sector in each country, would result in minor adverse competitiveness effects overall.

This measurement of price-setting power and the findings enable an important new dimension to be brought to bear in the assessment of a sector's vulnerability under ETR.

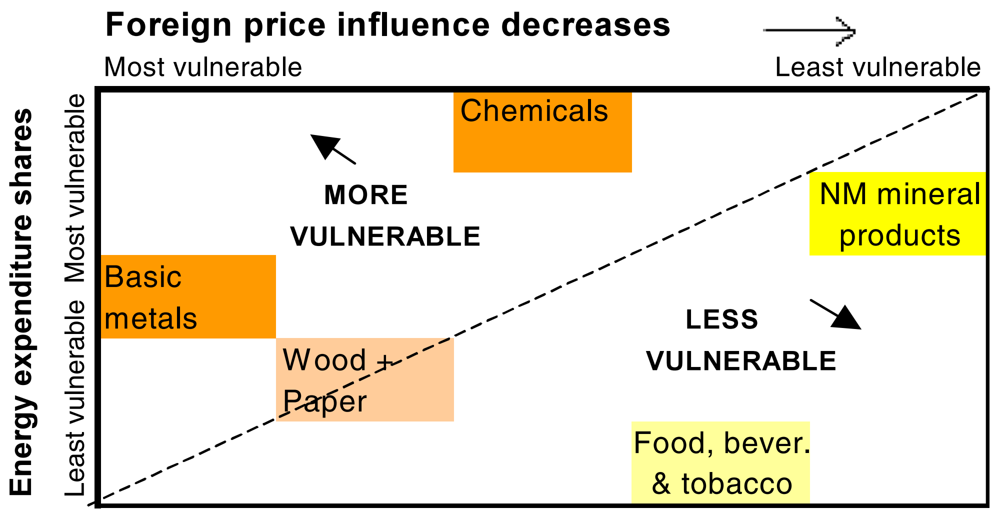
2.7.4 Price-setting power and vulnerability

Vulnerability of the selected sectors was initially assessed and ranked in terms of their unit energy costs in particular. The market power analysis just described additionally enabled the sectors to be ranked according to vulnerability in price-setting terms. The two sets of ranking measures, that is, the energy unit costs and the price-taking measure, can be combined to provide a more comprehensive view of the relative vulnerability of the selected sectors.

Chart 2.7.1 illustrates the situation for the ETR countries of the EU combined. The vertical axis shows increasing energy expenditure share and the horizontal axis shows increasing market power, that is, decreasing foreign price influence in price-setting. Vulnerability is highest in the top left-hand corner where the energy share is highest and price-setting ability is lowest. Vulnerability is lowest in the bottom right-hand corner.

The most vulnerable sectors are Basic metals and Chemicals in the top left-hand half of the chart. The Chemical sector has the highest energy expenditure share and Basic metals is the most exposed to the world price - it is the least able to pass on cost increases.

Chart 2.7.1 Vulnerability with respect to pricing power, ETR countries



Source: Ranking of ETR countries' energy expenditure shares from Table 2.2.1 and ranking of price-setting power from Section 2.7.3 and Table 2.5.1.

In the bottom right-hand corner of the chart are the less vulnerable sectors Food, beverages and tobacco and Non-metallic minerals products. Ranked in the middle in terms of vulnerability is Wood a Paper. The implication is that the introduction of ETR would require most attention to be paid to the effects of ETR on the competitiveness of Basic metals and Chemicals compared to Non-metallic mineral products, and less again on Food, beverages and tobacco. These rankings of vulnerability apply to the combined six countries that implemented ETR. Rankings for individual countries are given in Appendix 2.7 where the ranking of sectors for the UK, for example, are the same.

2.7.5 FDI and the threat of relocation

Recent studies that use more extensive data than earlier attempts typically find some evidence of moderate relocation from areas with stringent *environmental regulations*. In other words there probably is a so-called pollution haven effect but the indications are that it is small. Important factors that determine location are market size and labour costs, and judging from discussions with representative bodies a positive role is played by transparent and consistent rules and a quick permitting process.

It is stressed that the effects on FDI of environmental regulations may be different from the effects of ETR. FDI could be deterred or encouraged to relocate in order to avoid environmental taxes if, that is, serious attention is not paid to the recycling of the revenue and the problems of vulnerable sectors are ignored. If countries with which the sector must compete have less stringent environmental fiscal or regulatory policies than implied by the ETR then particular attention to recycling is required.

The manner of ETR implementation can avert industrial relocation by careful targeting of the recycled revenues to mitigate the effects of the tax side of the ETR. Because of this ETR has a major advantage over the regulatory route.

Among other possible measures that could be implemented to reduce the threat of relocation could be inducements to competing host countries in turn to strengthen their environmental policies, via trade agreements that promoted appropriate global safeguards and/or similar taxes.

2.7.6 Scope for technology adjustment

The scope for technology adjustment is the subject of a future work package. However a foretaste of the implications can be gained by looking at the technology adjustments that were possible in the UK in 1995, that is, before ETR introduction in the UK. Potential technological adjustments were available that entailed net financial savings, rather than net costs, judging from the net present values of the potential energy efficiency investments. The importance of this issue can be understood by taking the example of the sector producing Non-metallic mineral products. In 1995, by investing in energy efficient technology the sector could save over ten per cent of its energy, at positive Net Present Value (Entec). This means that if the price of energy rose by ten per cent, through ETR, the sector need not be affected if it invested in the energy-saving technology then available.

Potential technology adjustments available to energy intensive sectors in the UK had been estimated by Entec and can be used for illustrative purposes. The sectors can be ranked by scope for adjustment, starting with those that have most scope (i.e. the least vulnerable), as shown in Table 2.7.2.

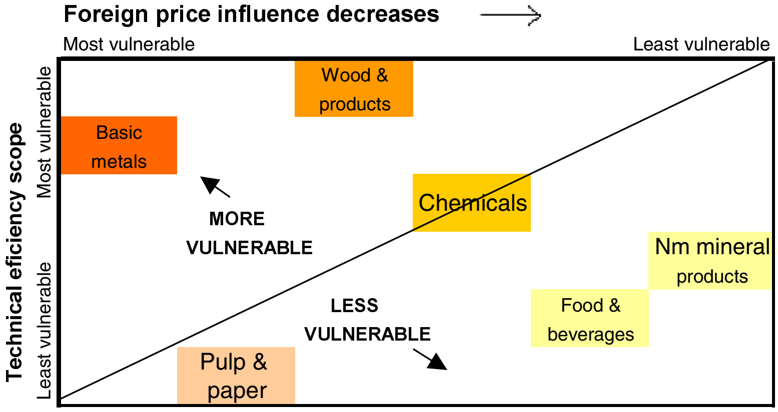
Table 2.7.2 Ranking of sectors by vulnerability with respect to scope for technological adjustment, UK 1995 (with NACE code)

21	Pulp, paper and paper products (most scope, least vulnerable)
15	Food and beverages
26	Non-metallic mineral products
24	Chemicals
27	Basic metals
20+36	Wood and wood products (least scope, most vulnerable)

Source: Entec/Cambridge Econometrics, 2003

The sectors now ranked according to their technological potential for energy efficiency adjustments can be incorporated into a similar chart. Chart 2.9.2 relates to the UK and, along with ranked vulnerability to price competition as before, it shows ranked vulnerability with respect to absence or scope for technological adjustment.

Chart 2.9.2 Vulnerability with respect to scope for technology and price-setting, UK



Source: Ranking of technology scope from Table 2.7.2 and ranking of UK price-setting power from Table 2.5.1 and Appendix 2.7.

At the extremes, it can be seen that in the UK Basic metals is again clearly in a relatively vulnerable position in the chart, now joined by Wood and wood products. Food, beverages and tobacco and the Non-metallic mineral products sectors are least vulnerable - they have modest potential for adapting technology and have scope for price setting. Chemicals and Pulp and paper fall in between.

It is stressed that these are relative placings, and their importance lies in how they can rank vulnerability and thereby indicate where to prioritise mitigation policies in the event of environmental tax reform.

2.7.7 Final summary

Initial screening based on intensities of energy expenditure and other characteristics was undertaken for all sectors. The purpose was to highlight sectors that could be vulnerable under ETR and to select those that would be subject to further study.

Econometric analysis explored the price-setting ability of the selected sectors in order to throw light on their market power - on whether they were price-setters or price takers. The results of the analysis were significant and plausible. The importance of these results is that a sector's price-setting ability and hence a major aspect of its relative vulnerability can be realistically assessed. Among the selected sectors, Basic metals had least and Non-metallic minerals had most market power. Where the foreign price was a constraint on price-setting, it was the German price that tended to dominate. The significance of this is that EU-wide application of environmental tax reform should give less cause for concern about loss of competitiveness.

From a survey of the literature on the pollution haven hypothesis it emerged that relocation of production is a possible outcome of the introduction of environmental regulations. This brings the advantages of ETR over environmental regulations into focus, because revenues are available that can help to prevent industrial relocation. This is provided that the revenue recycling is designed and targeted carefully. Global trade agreements would help stave off a 'race to the bottom' in terms of environmental regimes and better understanding is needed of the distinct potential advantages of ETR.

The scope for sectors to make profitable adjustments to their technology also has an important bearing on their vulnerability. Energy-saving investment cost curves can be used to assess each sector's scope for adjusting technology and thereby avoid the adverse effect of the tax side of ETR.

In the analysis so far it is the Basic metals sector that emerges as being vulnerable on quite a consistent basis. This is because it is energy intensive, it is a price-taker on the world market and its scope for adjusting technology is relatively low. A mitigating factor is its high labour intensity, meaning that any labour tax reduction brought about as part of the ETR could be to its benefit. The Chemicals sector shows similar tendencies though its scope for costless technology adjustment may not have been so constrained. At the other end of the selected sectors, the least vulnerable on the price-taking front is the Food, drink and tobacco

sector, which may also have had relatively good scope for adjusting its technology in the UK. However the sector tends not to be so labour intensive and would stand to benefit less from the revenue recycling.
Wood and paper stand in the middle though where technology potential is concerned in the UK (where the constituent parts Wood and wood products and Pulp and paper, could be separated) the former is vulnerable on technology and the latter has scope. The Non-metallic minerals sector along with Food, beverages and tobacco are the least vulnerable on these issues.

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Appendix 2.1 Screening for potentially vulnerable sectors

Screening for potential vulnerability was undertaken over all manufacturing sectors at the NACE 2-digit level. Appendix Table 2.1.1 shows for each sector the ratios of energy expenditure to value-added, to gross output and to gross operating surplus.

Appendix Table 2.1.1 Energy expenditure as a share of value-added, gross output and gross operating surplus, and labour intensity, %

Sector and NACE code		Energy expenditure as a share of value-added	gross output	operating surplus	Labour intensity of VA
Coke, refining petrol. & nucl. fuel	23	466%	73%	2893%	81%
Basic metals	27	24%	7%	162%	82%
Non-metallic mineral products	26	13%	6%	54%	73%
Pulp, paper & board products	21	12%	4%	52%	74%
Chemicals	24	12%	4%	36%	66%
Textiles	17	7%	3%	41%	81%
Rubber & plastic	25	7%	3%	38%	81%
Food & drink	15	6%	2%	19%	66%
Wood & wood products	20	6%	2%	18%	65%
Metal products	28	6%	3%	40%	84%
Machines	29	5%	2%	22%	75%
Shipbuilding, air & other transp. eq.	35	5%	2%	21%	77%
Furniture & misc.	36+37	4%	2%	13%	64%
Electrical machinery	31	4%	2%	16%	72%
Motor vehicles	34	4%	1%	29%	84%
Medical & precision instruments	33	3%	1%	12%	76%
Office machines & computers	30	3%	1%	12%	78%
Electronics	32	3%	1%	7%	60%
Apparel	18	3%	1%	13%	79%
Leather goods & footwear	19	2%	1%	7%	67%
Printing & publishing	22	2%	1%	7%	71%
Tobacco products	16	1%	0%	1%	31%
All Manufacturing	15 – 37	14%	5%	54%	73%

Source: Input-Output Supply and Use Tables, 2000. Office of National Statistics, UK.

Notes: The figures for energy bought include feedstock. This applies mainly to Coke, refined petroleum etc., and to a lesser extent to Chemicals. See Appendix Table 2.2.1 for ranking of all sectors including manufacturing, in a more detailed classification.

The data relate to the UK. The UK is a large open economy that has traded on a world scale over a long time, meaning that the UK manufacturing sector is reasonably homogeneous and unlikely to be subject to major distortions.[5] Sectors are ranked in descending order of intensity of energy expenditure to value-added, shown in the first column of Appendix Table 2.1.1. The fourth column in the table, which gives a measure of labour intensity, is the share of labour (compensation of employees) in gross value-added. Environmental tax reform often involves reducing taxes on labour and this column gives an indication of the impact of such a reduction on the sectors.

Leaving aside the top-ranked energy transformation sector (Coke, refining petroleum and nuclear fuel) where energy use includes feedstock and perforce energy intensity is high, there are several sectors in which expenditure on energy stands out. They are high users of energy whichever measure of expenditure intensity

[5] The variations across countries and within sectors were important considerations in the final choice made by the project partners.

is used. This cluster includes the four sectors Basic metals, Non-metallic mineral products, Pulp, paper and paperboard, and Chemicals.

Other sectors where energy plays an important though lesser role are Textiles, Rubber and plastic, Food & drink, Wood and wood products, Metal products and Machines. In this screening exercise the intention was to select 4 to 8 sectors for further analysis that include energy intensive sectors and also sectors with other characteristics that are considered to be important by the project partners.

Exposure to trade is another measure of potential vulnerability under a domestic carbon or energy tax regime. Sectors where the output is largely exported could be subject to pressure in the form of a foreign price constraint in the event of cost increases brought about by the introduction of such a tax. In addition, where there is a large imported share supplying the domestic market, sectors could be undercut by imports on which no carbon tax had been levied. These sectors are also potentially vulnerable.

Appendix Table 2.1.2 shows trade shares. Sectors are ranked in descending order of export share of total output, shown in the first column and, in the second column, the import share of total domestic sales is given. (Domestic sales consist of total output plus imports minus exports). The final column gives the destination shares of exports as between the EU 15 countries and the rest of the world. These data also relate to the UK.

Appendix Table 2.1.2 Export shares, import shares and destination of exports, %

Sector and NACE code		Exports share of total output	Imports share of domestic market	Destination of exports	
				EU	Non-EU
Office machines & computers	30	119%	114%	70%	30%
Leather goods & footwear	19	106%	102%	50%	50%
Electronics	32	104%	103%	64%	36%
Chemicals	24	73%	69%	58%	42%
Ship, air & other transport	35	73%	72%	39%	61%
Apparel	18	67%	84%	52%	48%
Medical & precision instruments	33	66%	67%	43%	57%
Motor vehicles	34	59%	67%	70%	30%
Electrical machinery	31	57%	60%	51%	49%
Machines	29	54%	54%	47%	53%
Tobacco products	16	51%	57%	43%	57%
Basic metals	27	50%	54%	57%	43%
Coke, refining petrol. & nucl. fuel	23	42%	37%	64%	36%
Textiles	17	40%	54%	54%	46%
Furniture & misc.	36+37	26%	42%	47%	53%
Rubber & plastic	25	23%	27%	63%	37%
Pulp, paper & board products	21	20%	37%	63%	37%
Non-metallic mineral products	26	17%	19%	57%	43%
Food & beverages	15	17%	27%	57%	43%
Metal products	28	15%	17%	61%	39%
Printing & publishing	22	10%	7%	48%	52%
Wood & wood products	20	6%	32%	77%	23%
All Manufacturing	15 - 37	45%	51%	57%	43%

Source: Input-Output Supply and Use Tables, 2000. Office of National Statistics, UK.
Note: Measured shares greater than 100 per cent arise because of difficulties in distinguishing country of origin from country of despatch in the compilation of trade statistics and because of discrepancies that arise in transferring from trade classification (SITC) to NACE classification.

Of the high energy users noted in the previous table it is seen here that the Chemicals sector has high trade shares in addition to high energy use. Trade shares of Basic metals fall in a middle category for manufacturing. For Non-metallic mineral products and for Pulp, paper and board products the trade shares are low (though in the case of the latter the shares for Finland and Sweden would be high, as seen in country data in the section on trade patterns). The chart below shows the information from the two tables on energy shares and export intensity combined, categorised by high, medium and low shares. (Import intensity is not materially different and is not shown.)

Appendix Chart 2.1.1 Energy expenditure share by export intensity - high, medium, low

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Export intensity</th></tr>
<tr><th>High</th><th>Medium</th><th>Low</th></tr>
<tr><th rowspan="3">Energy expenditure share</th><th>High</th><td>Chemicals</td><td>Basic metals
Textiles</td><td>Non-metallic mineral products
Pulp, paper & board products
Rubber & plastic
Food & beverages</td></tr>
<tr><th>Medium</th><td>Shipbuilding and o transp equip.
Electrical machinery</td><td>Machines
Furniture & misc.
Motor vehicles</td><td>Wood & wood products
Metal products</td></tr>
<tr><th>Low</th><td>Medical & precision instruments
Office machines & computers
Electronics
Apparel
Leather goods & footwear</td><td>Tobacco products</td><td>Printing & publishing</td></tr>
</table>

Source: Appendix Table 2.1.1 and Appendix Table 2.1.2 above. The ranked sectors were split into three groups and denoted high, medium and low. Sector 23 was omitted.

The sectors highlighted in Chart 2.1.1 were selected for further analysis in the project. On the basis of partner knowledge it was decided to split Chemicals into two parts, namely, Pharmaceuticals (NACE 24.4) and Basic chemicals excluding Pharmaceuticals (NACE 24 less 24.4).

The full data for all sectors relating to the UK are shown in Table 2.1.3 below.

Appendix Table 2.1.3 Energy expenditure as a share of value-added (ranked in descending order), gross output and gross operating surplus, and labour intensity, all sectors, % (Highlighted sectors come under the classification of Manufacturing)

NACE / SIC(92) code	Input-Output code	Sector	Energy expenditure as a share of: value-added	Energy expenditure as a share of: gross output	Energy expenditure as a share of: operating surplus	Labour intensity of VA
23	35	Coke ovens, refined petroleum & nuclear fuel	466%	73%	2893%	81%
40.1	85	Electricity production & distribution	212%	61%	324%	27%
40.2 + 40.3	86	Gas distribution	200%	59%	426%	46%
24.15	39	Fertilisers	74%	16%	318%	73%
24.13	37	Inorganic chemicals	50%	12%	447%	86%
24.14	38	Organic chemicals	45%	11%	219%	77%
26.5	52	Cement, lime and plaster	42%	17%	102%	55%
10	4	Coal extraction	36%	16%	123%	66%
27.1 to 27.3	54	Iron and steel	34%	8%	268%	83%
05	3	Fishing	33%	14%	41%	16%
62	96	Air transport	33%	13%	77%	56%
21.1	32	Pulp, paper and paperboard	25%	8%	82%	67%
60.2 + 60.3	94	Other land transport	25%	12%	85%	68%
24.16 + 24.17	40	Plastics & synthetic resins etc	25%	6%	86%	69%
24.7	46	Man-made fibres	22%	8%	64%	63%
26.4	51	Structural clay products	22%	12%	73%	67%
15.83	15	Sugar	22%	7%	53%	57%
61	95	Water transport	22%	7%	126%	82%
15.4	10	Oils and fats processing	18%	3%	47%	60%
24.11 + 24.12	36	Industrial gases and dyes	18%	7%	80%	75%
14	7	Other mining quarrying	17%	7%	52%	63%
02	2	Forestry	16%	7%	47%	64%

27.4	55	Non-ferrous metals	16%	4%	82%	79%
17.3	23	Textile finishing	16%	7%	95%	81%
15.7	13	Animal feed	13%	3%	62%	77%
27.5	56	Metal castings	12%	6%	99%	85%
26.1	49	Glass and glass products	12%	5%	53%	76%
60.1	93	Railway transport	11%	3%	62%	86%
01	1	Agriculture	11%	5%	17%	35%
11 + 12	5	Oil and gas extraction	10%	8%	11%	7%
26.2 + 26.3	50	Ceramic goods	10%	5%	57%	80%
17.51	25	Carpets and rugs	10%	4%	51%	79%
15.5	11	Dairy products	9%	2%	58%	82%
28.1	57	Structural metal products	9%	3%	61%	83%
17.1	21	Textile fibres	8%	3%	46%	80%
26.6 to 26.8	53	Articles of concrete, stone etc	8%	3%	32%	72%
51	90	Wholesale distribution	8%	3%	29%	69%
15.6	12	Grain milling and starch	7%	2%	25%	69%
35.1	78	Shipbuilding and repair	7%	3%	133%	93%
15.1	8	Meat processing	7%	2%	35%	79%
25.1	47	Rubber products	7%	3%	35%	79%
36.6 + 37	84	Miscellaneous manufacturing nec, recycling	7%	3%	14%	50%
21.2	33	Paper and paperboard products	7%	2%	33%	77%
25.2	48	Plastic products	7%	3%	38%	81%
29.6	67	Weapons and ammunition	6%	2%	30%	78%
24.6	45	Other chemical products	6%	3%	17%	64%
20	31	Wood and wood products	6%	2%	18%	65%
29.1	62	Mechanical power equipment	6%	2%	23%	73%
29.4	65	Machine tools	6%	3%	24%	75%
28.2 + 28.3	58	Metal boilers & radiators	6%	2%	54%	88%
15.81 + 15.82	14	Bread, biscuits etc	6%	2%	29%	79%
17.6 + 17.7	27	Knitted goods	6%	2%	38%	83%

41	87	Water supply	6%	4%	8%	24%
28.4 + 28.5	59	Metal forging, pressing, etc	5%	3%	46%	86%
28.7	61	Other metal products	5%	2%	37%	84%
29.5	66	Special purpose machinery	5%	2%	25%	77%
17.52 to 17.54	26	Other textiles	5%	2%	36%	84%
29.2	63	General purpose machinery	5%	2%	23%	76%
15.91 to 15.97	18	Alcoholic beverages	5%	2%	8%	36%
66	101	Insurance and pension funds	5%	1%	17%	69%
31.1 + 31.2	70	Electric motors and generators etc	5%	2%	16%	70%
15.2 + 15.3	9	Fish and fruit processing	5%	2%	17%	72%
15.98	19	Soft drinks & mineral waters	5%	1%	7%	28%
90	119	Sewage and sanitary services	4%	2%	13%	62%
35.3	80	Aircraft and spacecraft	4%	1%	17%	74%
52	91	Retail distribution	4%	2%	10%	51%
36.4 + 36.5	83	Sports goods and toys	4%	2%	10%	54%
29.3	64	Agricultural machinery	4%	1%	12%	65%
31.3	71	Insulated wire and cable	4%	1%	18%	75%
71	106	Renting of machinery etc	4%	2%	10%	57%
24.2	41	Pesticides	4%	1%	11%	62%
34	77	Motor vehicles	4%	1%	28%	84%
24.3	42	Paints, varnishes, printing ink etc	4%	1%	15%	72%
50	89	Motor vehicle distribution & repair, fuel	4%	2%	14%	69%
29.7	68	Domestic appliances nec	4%	2%	14%	72%
17.2	22	Textile weaving	4%	1%	23%	82%
36.2 + 36.3	82	Jewellery & related products	4%	2%	9%	57%
28.6	60	Cutlery, tools etc	4%	2%	13%	70%
17.4	24	Made-up textiles	4%	2%	21%	80%
31.4 to 31.6	72	Electrical equipment nec	4%	2%	14%	73%
15.85 to 15.89	17	Other food products	4%	1%	10%	64%
36.1	81	Furniture	4%	2%	14%	73%

55	92	Hotels, catering, pubs etc	3%	2%	12%	67%
19.1 + 19.2	29	Leather goods	3%	1%	15%	77%
67	102	Auxiliary financial services	3%	1%	13%	71%
32.1	73	Electronic components	3%	1%	10%	66%
75	115	Public administration & defence	3%	2%	20%	85%
35.2 + 35.4 + 35.5	79	Other transport equipment	3%	1%	12%	74%
65	100	Banking and finance	3%	1%	8%	58%
63	97	Ancillary transport services	3%	1%	11%	70%
64.1	98	Postal and courier services	3%	2%	19%	83%
73	108	Research and development	3%	2%	10%	72%
33	76	Medical and precision instruments	3%	1%	12%	76%
30	69	Office machinery & computers	3%	1%	12%	78%
18	28	Wearing apparel & fur products	3%	1%	13%	79%
15.84	16	Confectionery	2%	1%	8%	70%
32.2	74	Transmitters for TV, radio and phone	2%	1%	5%	55%
24.4	43	Pharmaceuticals	2%	1%	6%	59%
24.5	44	Soap and toilet preparations	2%	1%	7%	65%
45	88	Construction	2%	1%	5%	52%
64.2	99	Telecommunications	2%	1%	4%	48%
74.4	113	Advertising	2%	1%	6%	60%
72	107	Computer services	2%	1%	8%	72%
80	116	Education	2%	1%	30%	93%
22	34	Printing and publishing	2%	1%	7%	71%
32.3	75	Receivers for TV and radio	2%	1%	5%	63%
85.3	118	Social work activities	2%	1%	17%	89%
92	121	Recreational services	2%	1%	5%	59%
93	122	Other service activities	2%	1%	3%	33%
85.1 + 85.2	117	Health and veterinary services	2%	1%	7%	77%
74.5 to 74.8	114	Other business services	2%	1%	5%	64%
19.3	30	Footwear	2%	1%	4%	61%

74.12	110	Accountancy services	1%	1%	3%	55%
74.2 + 74.3	112	Architectural activities & technical consultancy	1%	1%	4%	69%
74.13 to 74.15	111	Market research, management consultancy	1%	1%	3%	63%
74.11	109	Legal activities	1%	1%	2%	49%
91	120	Membership organisations	1%	1%	3%	73%
16	20	Tobacco products	1%	0%	1%	31%
70.3	105	Estate agent activities	1%	0%	1%	58%
70.1 + 70.2(pt)	103	Owning and dealing in real estate	0%	0%	1%	25%
70.2 (pt)	104	Letting of dwellings	0%	0%	0%	4%
13	6	Metal ores extraction	0%	0%	0%	0%
95	123	Private households with employed persons	0%	0%	0%	92%
	124	Financial intermediation services (FISIM)				
	1 - 124	**All sectors**	9%	4%	26%	63%
	8 - 84	**Manufacturing sectors**	14%	5%	54%	73%

Source: Input-Output Supply and Use Tables, 2000. Office of National Statistics, UK.

Appendix 2.5 Modelling price-setting power

Review of previous work on price-setting behaviour and integrated markets

The law of one price (LOP) is a good place to start.[13] If the LOP held for all traded goods and preferences were identical across countries, then absolute[14] purchasing power parity (PPP) would hold. In practice, transport and distribution costs drive a wedge between domestic and foreign prices. But if these were constant, then relative[15] PPP holds.[16]

There is a mixed literature on empirical findings for the LOP and PPP. Research on prices and exchange rate movements has shown that relative prices of goods are systematically related to the exchange rate. For example, following Engel's (1999) approach, Obstfeld and Rogoff (2000) computed the correlation between the exchange rate and the relative prices of tradables and non-tradables over time in the United States, Germany, France and Japan and showed that the relative prices of tradables exhibited very little mean-reversion, i.e. they could be non-stationary. However, a number of empirical problems emerged because of aggregation issues and the failure to compare like-with-like when comparing prices across countries. Researchers have therefore focussed on industry data. These provided evidence that pass-through was more complete and somewhat faster. In our work using aggregated data reported below, we use sector-specific price indices for producer prices, calculated in domestic price terms.[17]

Market segmentation and pricing to market

The repeated empirical failures of PPP encouraged the development of theories based on strategic interaction and market segmentation. The argument in brief is that firms with monopoly power, selling differentiated products, have an incentive to charge different prices in markets where preferences differ. In a given market, their monopoly power (which depends on the elasticity of demand they face for their products[18]) and thus their pricing power should be gauged by the price they charge relative to their competitors' price. Changes in environmental taxes affect these relative prices and therefore the monopoly power and thus firm's pricing decisions: as a result the ETR pass-through may be full where the firms in the sector are price setters.

In line with the finding by Bergin and Feenstra (2001) for general equilibrium models, even with segmented markets, if preferences are identical and demand elasticities unchanged following a shock to the exchange rate, producers have no incentive to set different prices in different markets. Firms will *ex ante* set prices as a constant mark-up over marginal costs and hence PPP will hold. In the event of a shock, even if prices are sticky, relative prices will change eventually. Deviations from the long-run relationship are likely to be transitory. The desired mark-up is constant and firms will make price adjustments once they have a chance to do so. In this vein, we impose PPP for the long-run structural relationship between exchange rates and foreign prices.

Data

There are two basic sources for quarterly data on sectoral output prices, with a sufficient time span. The OECD compiles one set and the other set is compiled by EUROSTAT. The OECD Statistical Compendium 2004-2 "Indicators of Activities for Industry and Services ISIC Rev.3" (ceased end

[13] If agents are profit and utility maximisers and transportation, resale and distribution are costless then, due to arbitrage, identical goods command the same price in common currency terms. If firms are also price takers, this is the perfectly competitive paradigm.
[14] Absolute PPP is where all (common currency) prices for identical goods are equal.
[15] Relative PPP is where (common currency) prices grow at the same rate.
[16] In the estimations that follow, we estimate on the basis of price indices, not on absolute prices, and therefore we can only test for relative PPP instead of absolute PPP.
[17] Aggregation issues were not the only arguments against writing off market integration. In open economies, changes in exchange rates impinge on producers' costs, but cost measures may often fail to pick up exchange rate effects.
[18] In a standard Dixit-Stiglitz imperfect competition model, a firm's mark-up is inversely related to the elasticity of demand it faces. The greater the elasticity of demand, say because of greater availability of substitutes, the lower the monopoly power of a firm and hence the lower is the margin.

2001) was used to extract producer prices (1995=100) for the countries of interest – Denmark, Germany, Finland, Netherlands, Sweden, UK and on the US price as the 'world price'.[19] These were available as a domestic price index constructed in national currency. Corresponding domestic producer price indices at the sectoral level (NACE code) were available from EUROSTAT from 1990 (reference IO7qprin) onwards. The OECD series was used after updating with the appropriate rate of change in the price from the corresponding price series up to quarter 4, 2004.

The domestic manufacturing wage for the entire period is available from the OECD and is calculated as a quarterly index (2000=100) of hourly earnings in all manufacturing for each country. Sectoral specific wage rates were not available.

The exchange rates used were obtained from EUROSTAT (Ameco) and are represented as a quarterly average where one DM, US dollar or SEK is equal to so many units of domestic currency. Post Euro values were converted back to domestic currencies existing prior to the introduction of the Euro in order to achieve a consistent exchange rate time series.

The following time series are analysed for the 30-year period Q1 1975 to Q4 2004:

XXCHEMPR : domestic producer price for Chemicals (1990=1)
XXBASMETPR : domestic producer price for Basic Metals (1990=1)
XXFBTPR : domestic producer price for Food, Beverages and Tobacco (1990=1)
XXNMETPR : domestic producer price for Non-metallic Mineral Products (1990=1)
XXPAPPR : domestic producer price for Paper and Paper Products (1990=1)
XXWOODPR : domestic producer price for Wood and Wood Products (1990=1)
XXUSD : 1 US dollar = units of domestic currency
XXDE : 1 German Deutschmark = units of domestic currency
XXSW : 1 Swedish Kroner = units of domestic currency
Where XX = DE, DK, FI, IE, NL, SW, UK, US

DEMANW : All manufacturing manual wage index for Germany
DKMANW : All manufacturing manual wage index for Denmark
FIMANW : All manufacturing manual wage index for Finland
IEMANW : All manufacturing manual wage index for Ireland[20]
NLMANW : All manufacturing manual wage index for the Netherlands
SWMANW : All manufacturing manual wage index for Sweden
UKMANW : All manufacturing manual wage index for the United Kingdom
All of the above wage rates are in index form, 2000 = 1.000

The data employed in this study are graphically displayed in Appendix Charts 2.5.1. For each sector there is a graph of a logarithmic transformation of the time series data and a graph of the first differences of the logarithmic transformations.

The prefix 'L' stands for the natural logarithm of the time series and 'D' denotes differencing of the relevant time series. All econometric estimations in this section have been carried out using Eviews 5.0.

[19] Slovenian price data were not available from the OECD.
[20] Ireland was included in the dataset reported here.

Econometric issues
The first step is to test for a unit root. In essence this is to show whether the data conform to the requirements for the relationship not to be spurious. Appendix Table 2.5.1 summarises the results for the price variables of unit root tests on levels and in first differences of the data. They are tested for unit roots and their order of integration using an ADF test. Strong evidence emerges that the series are generally I(1). The relationship we seek is a cointegrating one.

It is well known that systems in which non-stationary variables are cointegrated can be described by error correction mechanisms (e.g. Granger, 1986; Engle and Granger, 1987). The Granger representation theorem states that if a set of variables are cointegrated, then there exists a valid error-correction representation of the data. Thus, if Y_t and X_t are both I(1) and have a cointegrating vector $(1,-\beta)$', there exists an error-correction representation

$$\Delta Y_t = \alpha_1 + \lambda(Y_{t-1} - \beta_1 X_{t-1}) + \sum \alpha_2(i)\Delta y_{t-i} + \sum \alpha_3(i)\Delta X_{t-i} + \varepsilon_{yt}$$

where β = the parameters of the cointegrating vector and ε_{yt} = white-noise disturbance with no moving average part and α_i are all parameters.

If Y_t and X_t are both I(1) and have a long-run relationship, there must be some force that pulls the variables back in line. The error correction model does exactly this: it describes how the variables behave in the short-run consistent with a long-run relationship. The systematic dynamics are kept as simple as possible in our estimation with just one lag.

Further if X_t does not adjust to the equilibrium error (has a zero adjustment parameter), it is weakly exogenous for β (as defined by Engle, Hendry and Richard 1983). This means that we can include ΔX_t in the estimated equation without affecting the error correction term $-\lambda(Y_{t-1} - \beta X_{t-1})$ and therefore the long run relationship.[21] Lambda is the speed of adjustment parameter where a higher value indicates a faster convergence from short-run dynamics to the long-run situation. We include both the domestic cost and foreign price effect within the ECM term as members of the *X* vector. Estimation of the nonlinear parameterisation of the ECM results in super-consistent estimators of the long-run coefficients.[22] We do not consider dynamic homogeneity i.e. that the long-run domestic price level is affected by the growth rate of prices and costs. We employ a specification that includes one lag in the dynamic terms, where the long-run margin is driven by the levels of domestic costs variable and the competitor price level (PPP imposed[23]). The econometric tests are shown in Appendix Table 2.5.1.

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[21] That is, we can condition upon X_t in the error correction model for Y_t.

[22] In investigating the price to market hypothesis, the traditional approach of first differencing disregards potentially important equilibrium relationships amongst the levels of the series to which the hypotheses of economic theory usually apply (Engle and Granger 1987). In this single equation ECM, this information is maintained.

[23] Multi-cointegration applies here where the combination of foreign price and exchange rate is cointegrated with domestic wage costs.

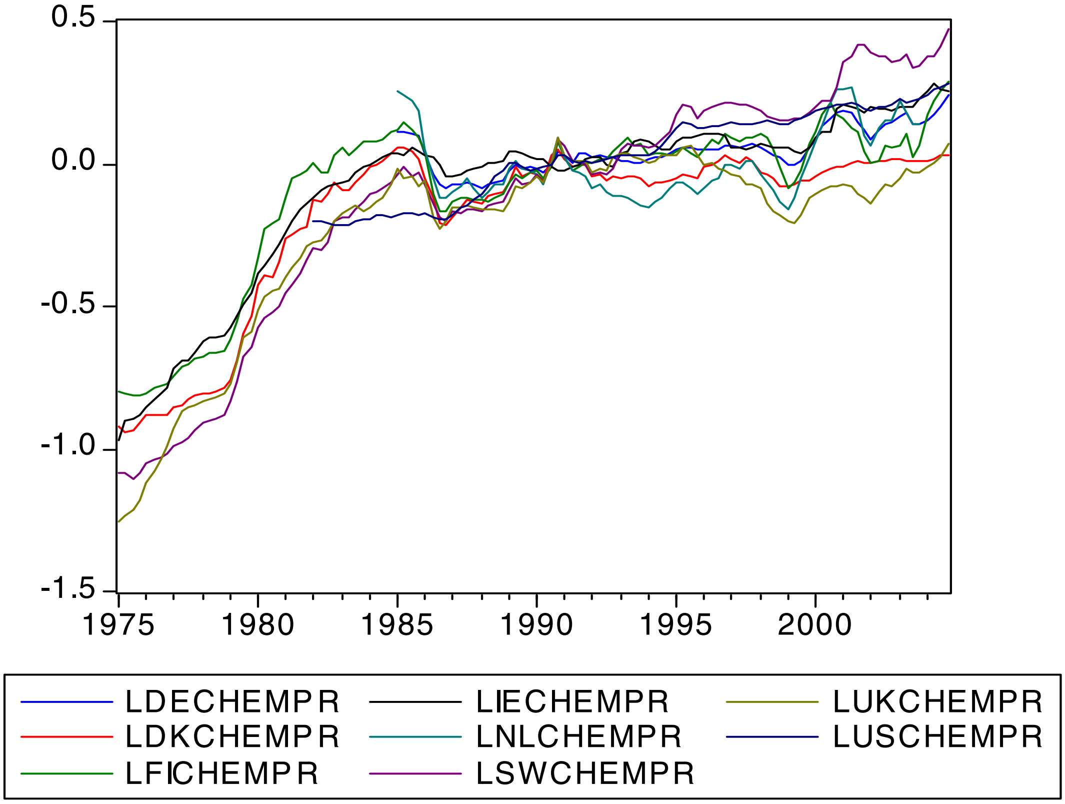
Appendix Charts 2.5.1 Cointegration analysis for price variables
Prices are expressed in levels (first graph) and as first differences in the second graph, logged.

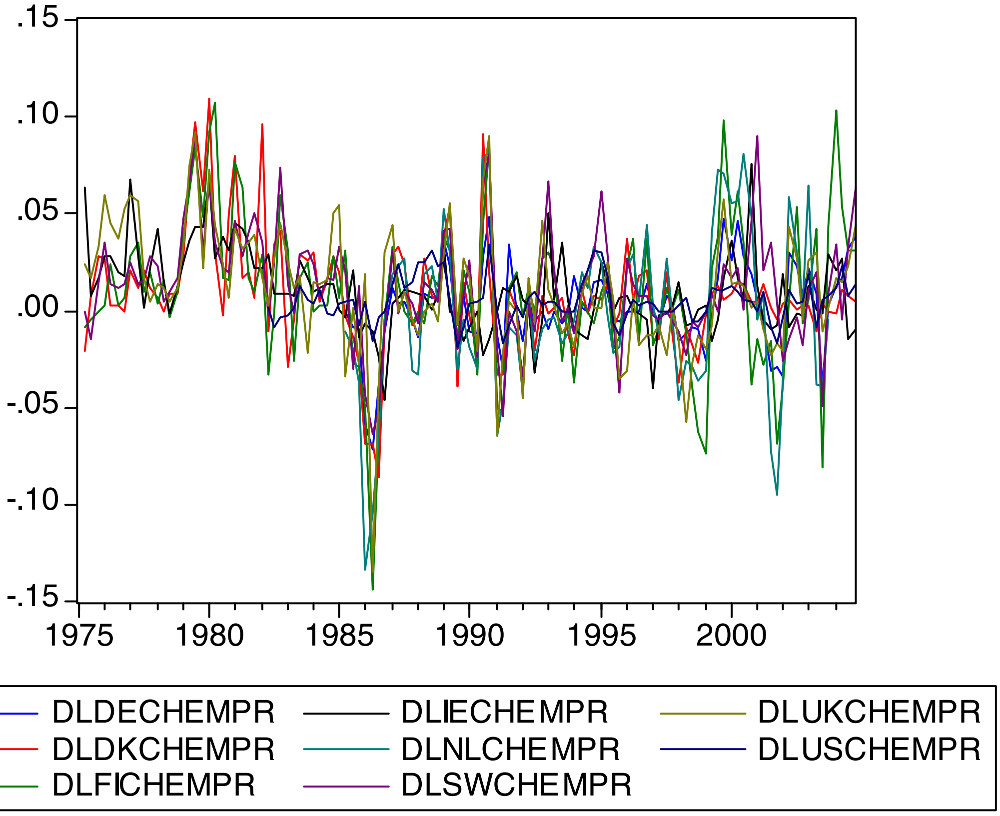
The charts' legends are as follows:

D = First differences
L = logged
DE = Germany
DK = Denmark
FI = Finland
IE = Ireland
NL = Netherlands
SW = Sweden
UK = United Kingdom
PR = price
CHEM = Chemicals
BASMET = Basic metals
FBT = Food, beverages and tobacco
NMET = Non-metallic mineral products
PAP = Paper and paper products
WOOD = Wood and wood products

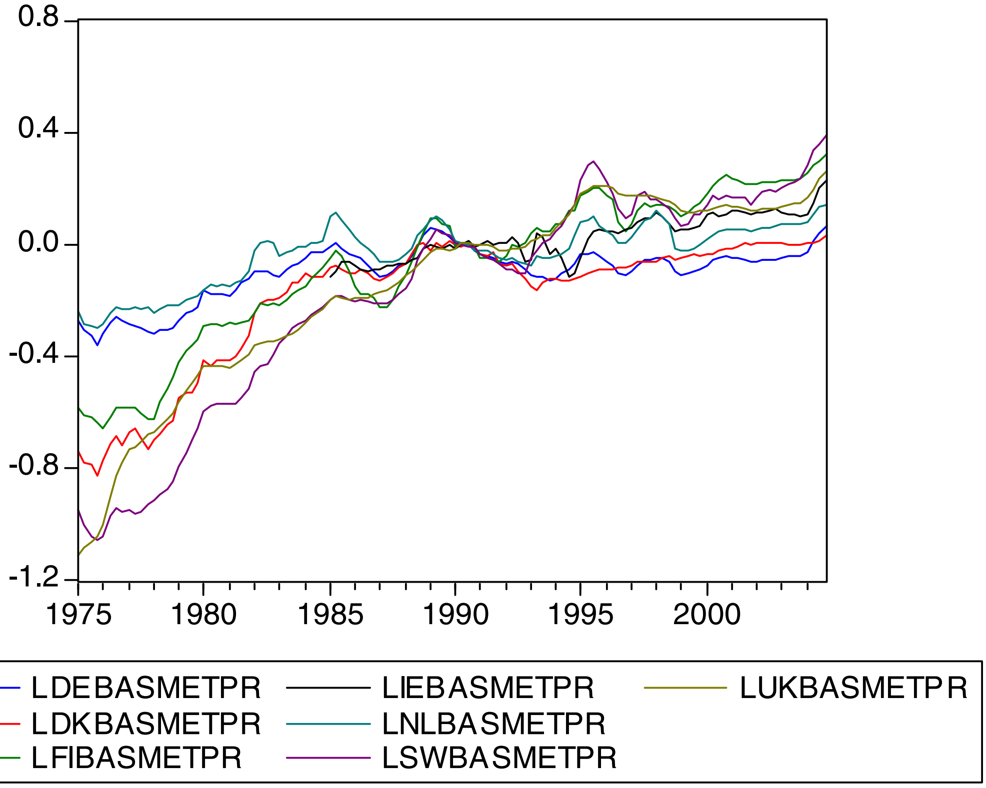
Ireland is included in the data-set, though not being an ETR country it is not included in the analysis.

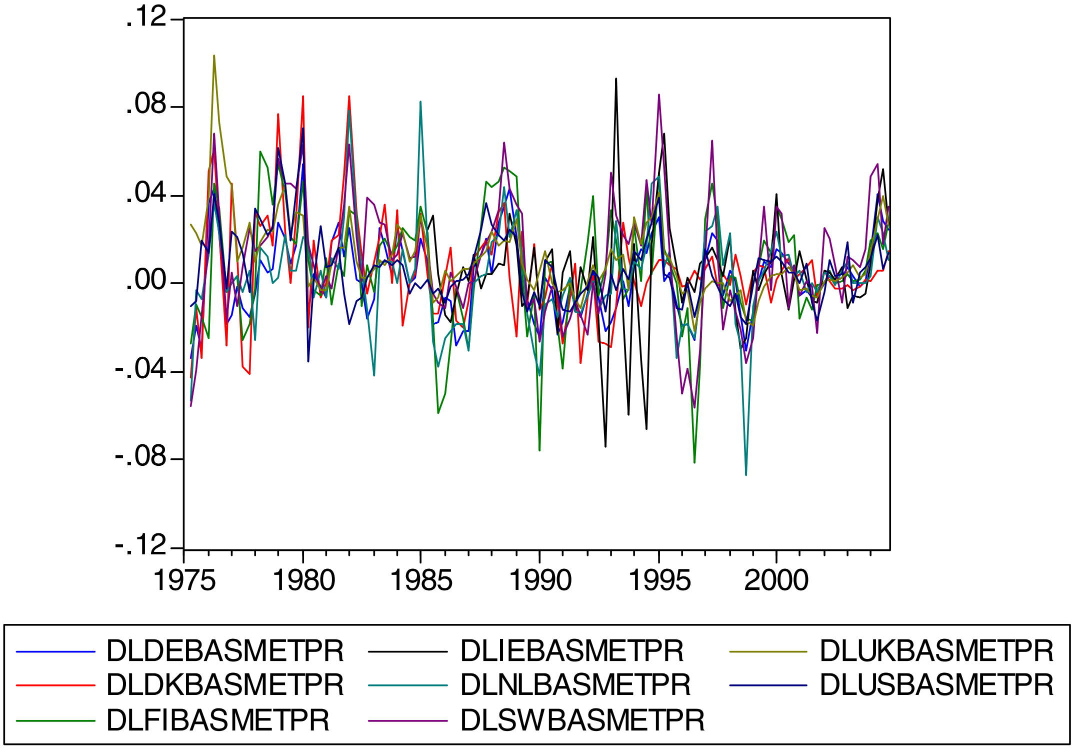
Chemicals



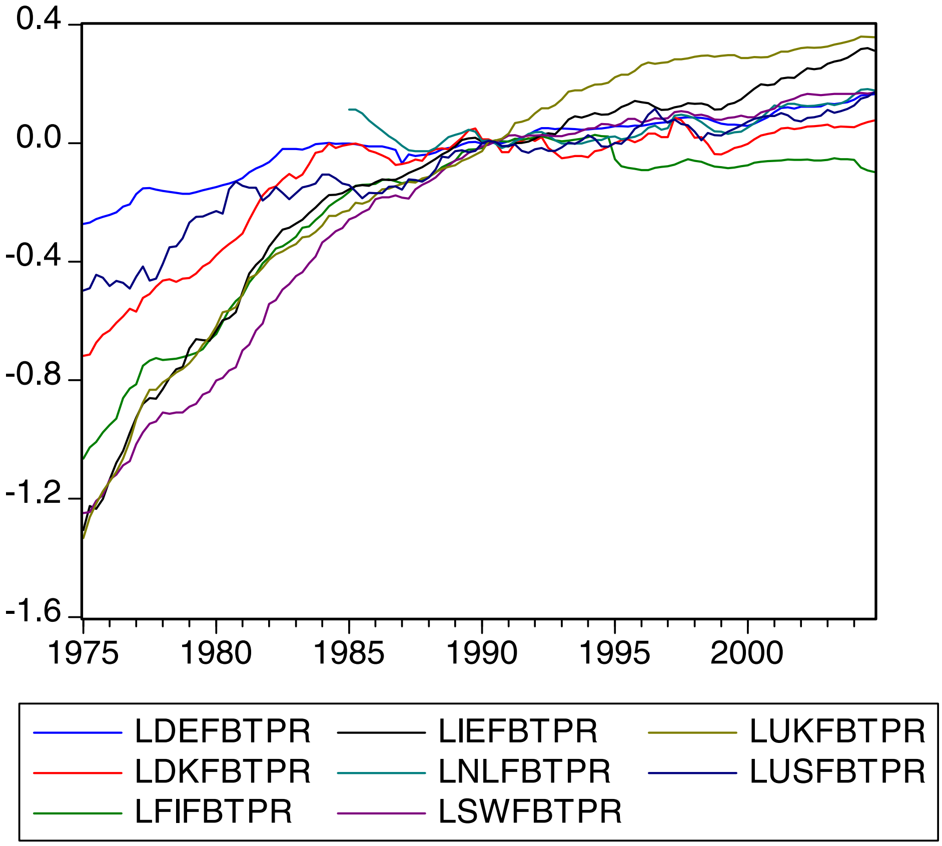


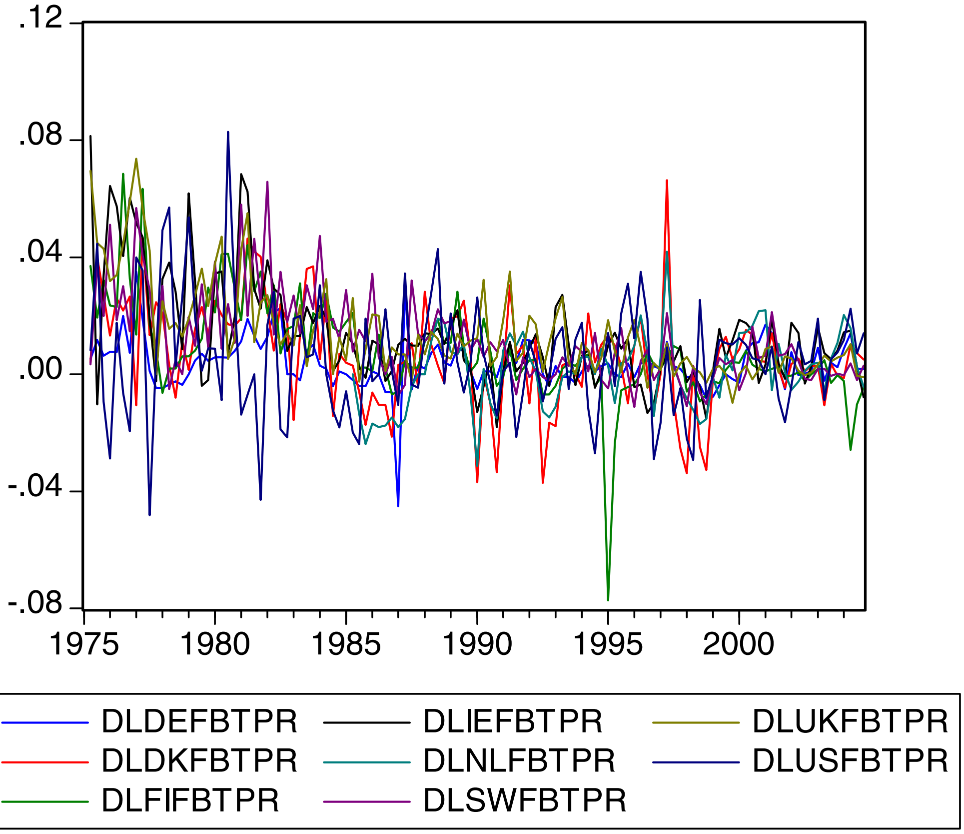
Basic Metals



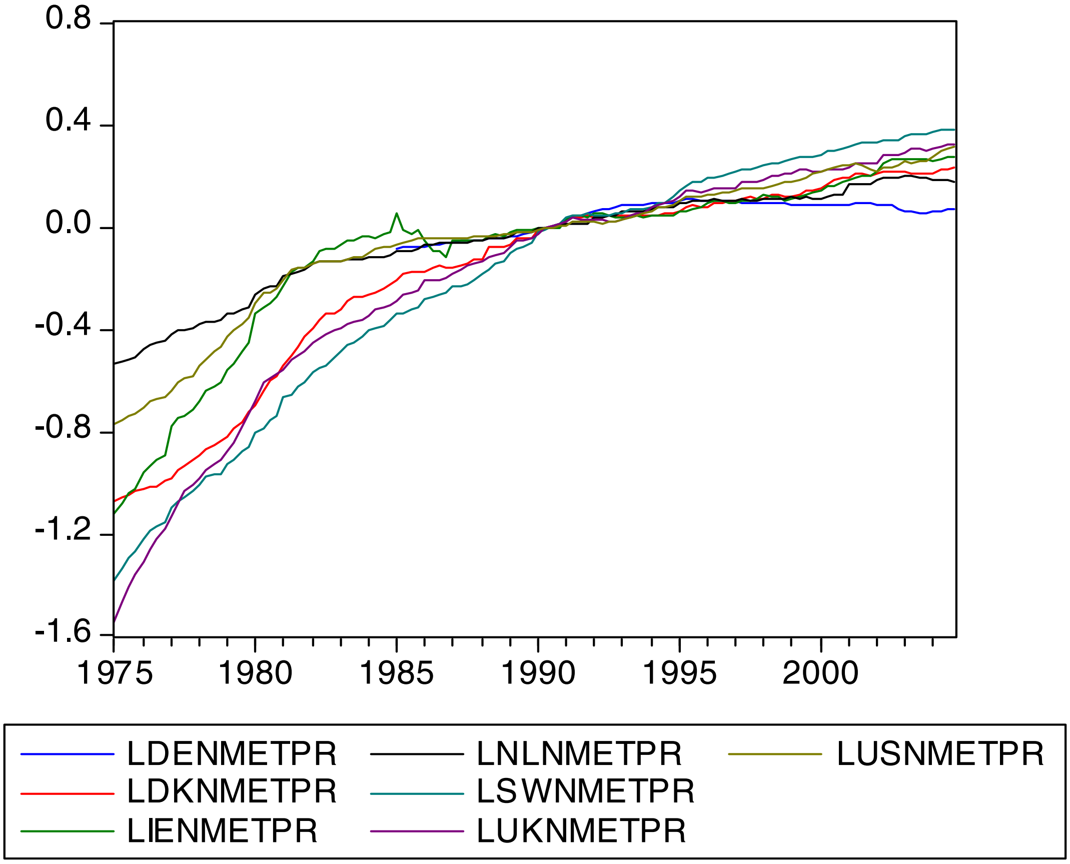


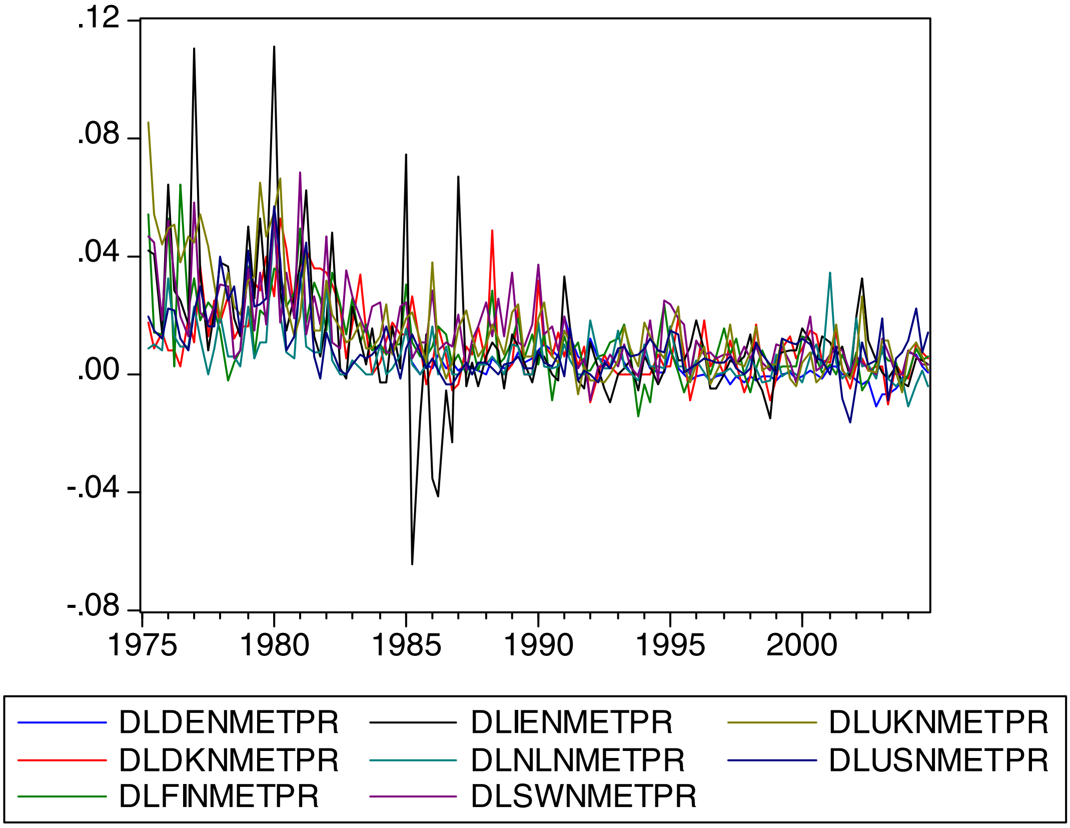
Food, Beverages and Tobacco



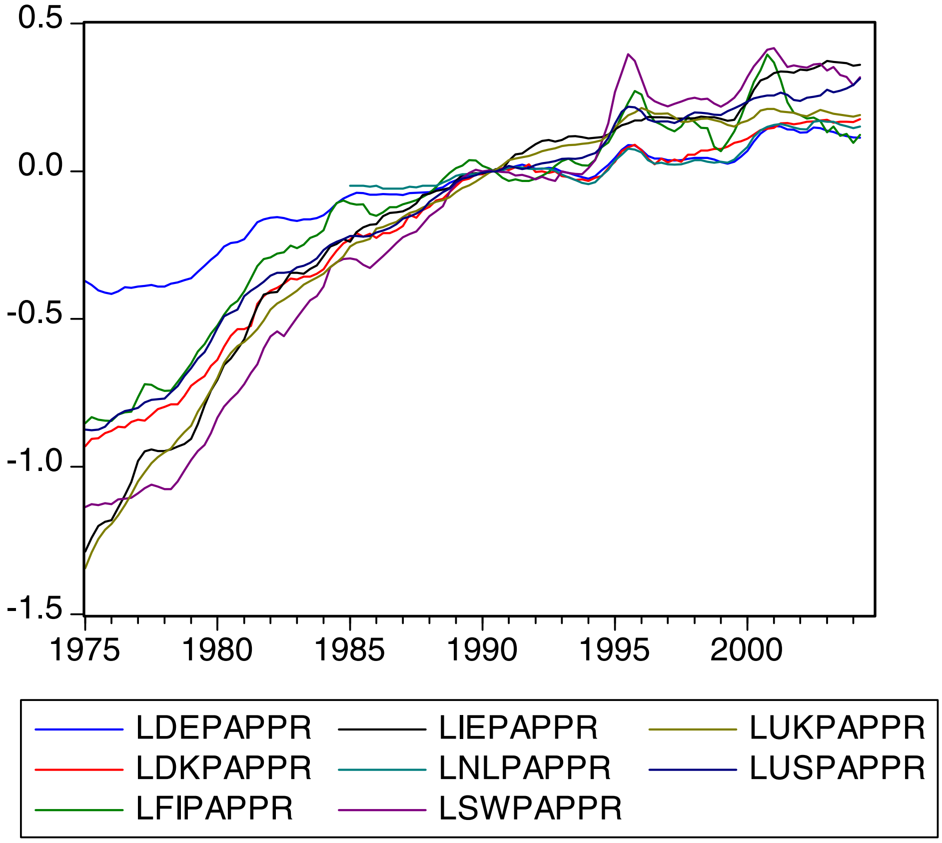


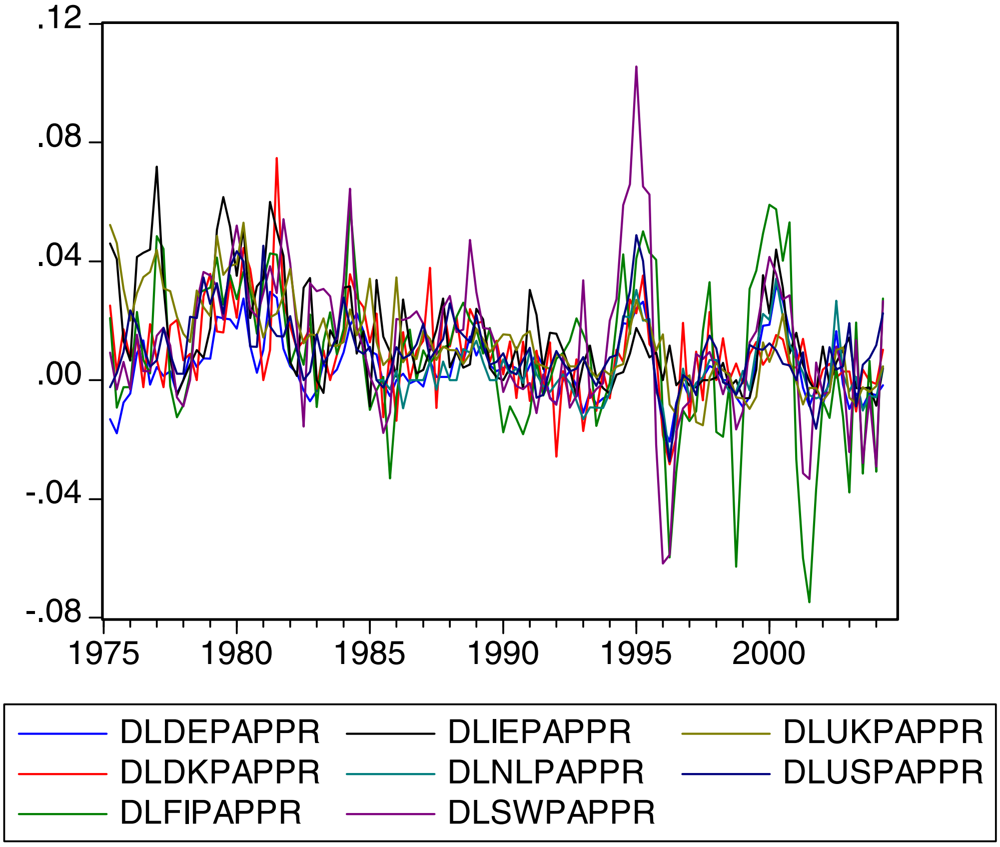
Non-metallic mineral products



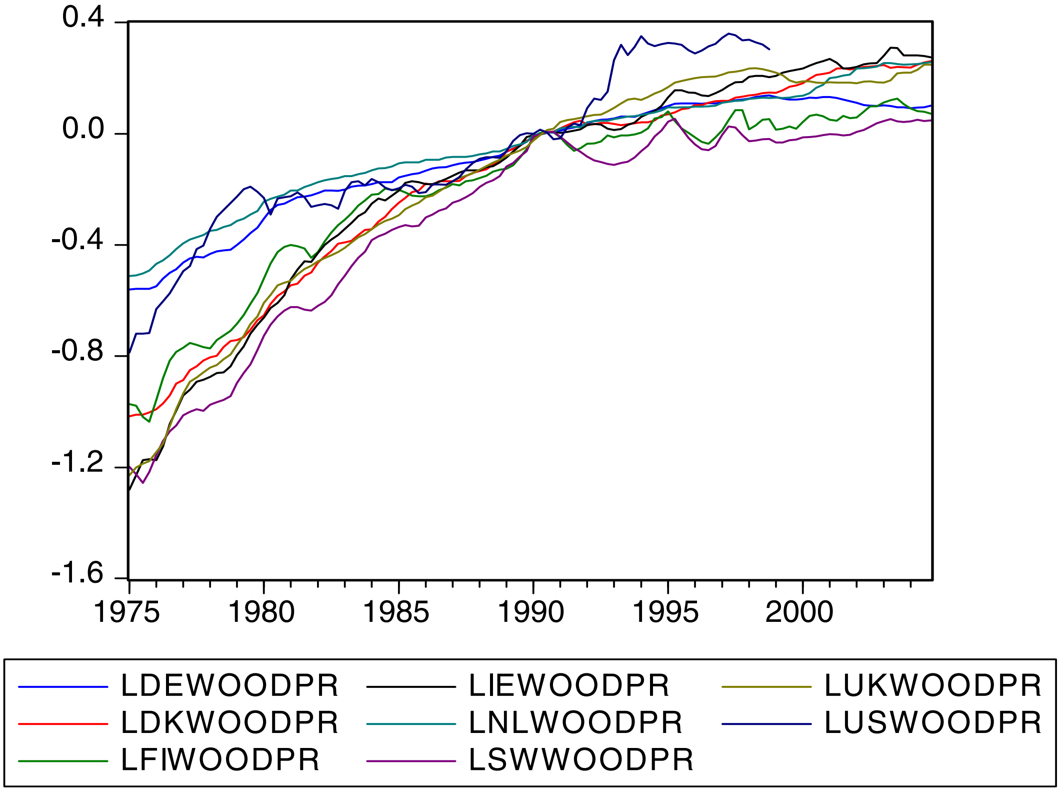


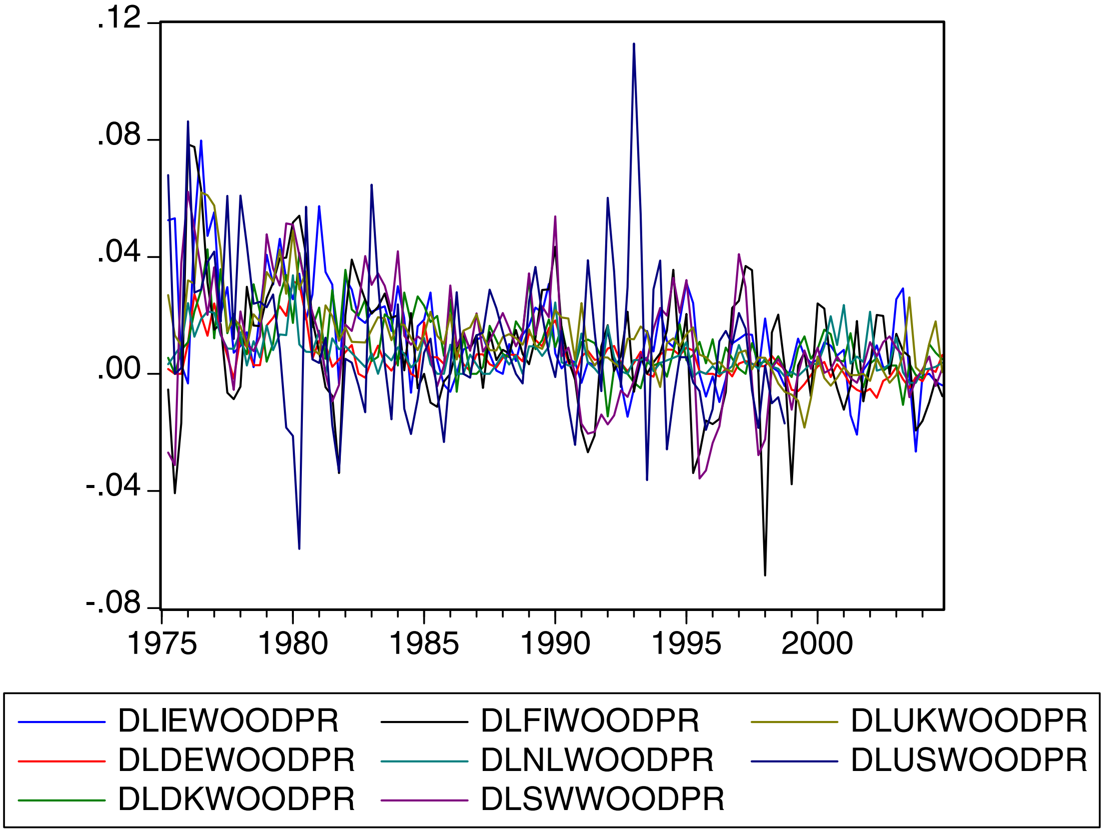
Paper and Paper Products





Wood and Wood Products




.12
.08
.04
.00
-.04
-.08
1975
1980
1985
1990
1995
2000
DLIEWOODPR
DLFIWOODPR
DLUKWOODPR
DLDEWOODPR
DLNLWOODPR
DLUSWOODPR
DLDKWOODPR
DLSWWOODPR

Econometric Tests

A Johansen test strongly rejects the null of no cointegration of the dependent and key independent variables at the 5% level, that is, they tested satisfactorily. Given the result that a unique cointegrating relationship exists, a single equation ECM offers a robust alternative to the Johansen method. Validity is conditional on the regressors being weakly exogenous[1], but we show that this condition is satisfied. Thus the estimation can proceed in the single-equation framework outlined above. Single equation estimates should be reliable and a well-determined t statistic on the ECM term is further evidence of cointegration. Additional tests for unit roots were undertaken for the price variables, interest focusing on foreign prices that the regressions tested for influence on the domestic price. Results are shown in Appendix Table 2.5.1.

[1] In a cointegrated system, if a variable does not respond to the discrepancy from the long-run equilibrium, it is weakly exogenous, that is, the speed of adjustment parameter is 0.

Appendix Table 2.5.1: Unit Root Tests

	Level	First Differences
	ADF test statistic	ADF test statistic
LDEBASMETPR	-3.315497	-5.986174***
LDKBASMETPR	-2.689924*	-8.359629***
LFIBASMETPR	-1.568949	-6.104499***
LIEBASMETPR	-0.343549	-5.547648***
LNLBASMETPR	-2.598586*	-6.701238***
LSWBASMETPR	-1.871067	-5.493550***
LUKBASMETPR	-3.237086**	-4.188560***
LUSBASMETPR	-3.189334**	-3.401767***
LDECHEMPR	-1.330966	-4.915669***
LDKCHEMPR	-2.962546**	-7.000909***
LFICHEMPR	-2.212823	-6.790495***
LIECHEMPR	-3.452354***	-6.803949***
LNLCHEMPR	-3.159378**	-5.440110***
LSWCHEMPR	-1.996497	-6.833328***
LUKCHEMPR	-3.897648***	-7.34932***
LUSCHEMPR	-0.439414	-5.204615***
LDEFBTPR	-1.855558	-5.190388***
LDKFBTPR	-4.054082***	-7.484247***
LFIFBTPR	-4.326288***	-3.774157***
LIEFBTPR	-4.104027***	-2.838678**
LNLFBTPR	-1.469798	-4.694399***
LSWFBTPR	-3.247706**	-2.765823*
LUKFBTPR	-4.929782***	-2.587562*
LUSFBTPR	-2.012392	-4.839287***
LDENMETPR	-1.954511	-2.406641
LDKNMETPR	-3.013959**	-1.791162
LFINMETPR	-6.842790***	-4.144532***
LIENMETPR	-6.652777***	-2.941475**
LNLNMETPR	-2.355987	-2.109424
LSWNMETPR	-3.669447***	-2.504838*
LUKNMETPR	-5.059891***	-2.759671**
LUSNMETPR	-1.992435	-1.908696
LDEPAPPR	-2.093627	-5.394902***
LDKPAPPR	-2.953416**	-3.220020***
LFIPAPPR	-2.021902	-5.405187***
LIEPAPPR	-3.470909**	-5.316844***
LNLPAPPR	-1.118458	-4.005505***
LSWPAPPR	-1.641998	-4.828684***
LUKPAPPR	-4.850024***	-4.230459***
LUSPAPPR	-2.462221	-4.873529***
LDEWOODPR	-3.409769**	-2.037768
LDKWOODPR		-3.083240***
LFIWOODPR	-3.095870**	-5.883673***
LIEWOODPR	-4.413811***	-5.580623***
LNLWOODPR	-2.435048*	-3.394687**
LSWWOODPR	-3.588209***	-4.895384***
LUSWOODPR	-2.135125	-3.561840***
LUKWOODPR	-4.660079***	-3.139922**

Critical values: 1% level = -3.48655; 5% level = -2.886074; 10% level = -2.579931.
Note: ADF is the Augmented Dickey-Fuller Test for unit roots. The null hypothesis that the series is not stationery is rejected if the test statistic exceeds the critical value in absolute terms. The lag length is based on the Schwarz Information Criterion.

Appendix 2.7 Ranking by unit energy costs and market power

This appendix sets out the ranking by decreasing vulnerability. Chart 2.7.1 showed this for ETR countries combined, and here it is shown for individual ETR countries by looking at **energy expenditure shares of value-added** alongside **market power** as measured by foreign price influence.

The model results on market power were used for ranking vulnerability, though this should be viewed as approximate because it is not an exact method. The ranking method was based mainly on the significance and size of the coefficient on the variable Foreign Price in Table 2.5.1(b), with consideration being given to Table (a). After variables with significant foreign price coefficients were exhausted, those with significant domestic costs were used to inform the ranking.

DENMARK: (the most vulnerable sectors are at the top of each column)

Expenditure shares	**Foreign price influence**
Basic metals	Food beverages and tobacco
Non-metallic mineral products	Basic metals
Food beverages and tobacco	Paper
Wood + Paper	Non-metallic minerals

Note: Wood and wood products and Chemicals are not well-modelled and are therefore omitted. In the expenditure shares Wood is included with Paper.

WEST GERMANY:

Expenditure shares	**Foreign price influence**
Basic chemicals	Paper
Pharmaceuticals	Chemicals
Wood + Paper	Wood

Note: The shaded sectors are those where the issue of different classification between the two columns arises. Where the sectors are contiguous consistency can be maintained by amalgamation.

FINLAND:

Expenditure shares	**Foreign price influence**
Basic metals	Basic metals
Wood + Paper	Non-metallic mineral products
Non-metallic mineral products	Wood

NETHERLANDS:

Expenditure shares	**Foreign price influence**
Basic chemicals	Basic metals
Basic metals	Chemicals
Pharmaceuticals	Non-metallic mineral products
Non-metallic minerals	Wood
Wood + Paper	Food beverages and tobacco
Food beverages and tobacco	

SWEDEN:

Expenditure shares	**Foreign price influence**
Basic metals	Paper
Basic chemicals	Basic metals
Non-metallic mineral products	Chemicals
Pharmaceuticals	Wood
Wood + Paper	Non-metallic mineral products

UK:

Expenditure shares	**Foreign price influence**
Basic chemicals 1	Basic metals 1
Non-metallic mineral products 2	Paper 2
Basic metals 3	Wood
Wood + Paper 4	Chemicals 3
Pharmaceuticals	Food beverages and tobacco 4
Food beverages and tobacco 5	Non-metallic mineral products 5

EU-ETR:

Expenditure shares	**Foreign price influence**
Basic chemicals 1	Basic metals 1
Pharmaceuticals	Paper 2
Non-metallic mineral products 2	Wood
Basic metals 3	Chemicals 3
Wood + Paper 4	Food beverages and tobacco 4
Food beverages and tobacco 5	Non-metallic mineral products 5

It is the ranking from this last table that is used for the vulnerability charts in the main text, in the concluding section.

Improvements in Energy Efficiency and Gross Carbon-energy Tax Burdens in Eight Energy-intensive and Less Energy-intensive Sectors:

A sub-sector perspective

WP3

Anders Ryelund,
NERI, University of Aarhus

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1 Introduction

The present paper explores competitiveness issues in relation to carbon-energy taxation and environmental tax reform by offering an inspection of the data and time-series for energy costs and economic output that have been established in the COMETR database for eight industrial sub-sectors at NACE 3-digit level under Work Package 3. This exercise has been carried out in order to make the basis for the subsequent econometric analyses in other WP3-work on the basis of these data more transparent.

In 'The comparative advantage of nations' (1990) Michael Porter introduced the idea that a trade-off does not necessarily exist between environmental regulation and economic competitiveness. The Porter hypothesis thus states that 'properly designed environmental standards can trigger innovation that may partially or more than fully offset the costs of complying with them' (Porter, 1991: 96 and Porter & van der Linde, 1995: 98). According to Porter, policy instruments aimed at environmental improvements will, as a spin-off, produce economic benefits for the regulated companies, termed 'innovation offsets'.

1.1 Policy instruments and their possible offsets

Porter and van der Linde describe six possible consequences of environmental regulation. First of all environmental regulation can focus attention on resource inefficiencies and technological improvements that have the potential to secure greater efficiency in the consumption of inputs. Second, regulation can improve focus on information gathering which reveals potential problems in the production process. Third, regulation reduces economic uncertainty surrounding investments designed to bring about environmental improvement. Fourth, environmental regulation spurs innovation in relation to new products. Environmental regulation creates pressure from outside a sector on enterprises within and constitutes an incentive for alternative thinking, so-called 'out-of-the-box' innovation. Fifth, regulation prevents a prisoner's dilemma-type situation from occurring, where a firm in the transitional phase to a new technological period may choose to gain economic advantage by unilaterally avoiding a change in environmental behaviour at that time. Environmental policy instruments prevent enterprises defecting and hence ensure that cost–efficient, innovation-based solutions are developed. Finally, when changing environmental behaviour creates incomplete offsets in both the short and medium terms, environmental policy instruments are required to ensure the changes in environmental behaviour that will create positive offsets in the long run (Porter&van der Linde, 1995: p.99-100).

According to Porter and van der Linde the six consequences, as identified above, can be evaluated in terms of the 'innovation offsets' which may arise in private enterprises. Porter argues that innovation arising from environmental regulation can bring about economic benefits in private enterprises in three basic ways; via process offsets, product offsets and abatement. Innovation represents a common denominator with regard to the six consequences and the three basic ways enterprises can gain offsets when faced with environmental policy instruments. First of all, a more efficient consumption of inputs combined with innovation and investment in the production process can reduce product costs and thereby facilitate a larger surplus. It has been described in several studies how corporations like 3M, DuPont, Hitachi, etc have accomplished significant economic gains as a result of e.g. raised environmental awareness, reduced input-output ratios or substitution to less damaging substances, which moreover may represent less costly alternatives (Porter&van der Linde, 1995:102). Secondly, Porter argues that improvements in product quality follow naturally as a side effect of regulation. Regulation forces enterprises to omit or decrease the use of certain inputs. Regulation can be seen as an incentive to develop an existing product or to improve product quality. Improved product quality gives the product a higher market value; the regulated company can sell more of its products at a better price, thereby improving its surplus. Thirdly, policy instruments can induce companies to manage pollution more intelligently. Pollutants can be reduced at the source – whereby expenses associated with end-of-pipe abatement are reduced. Policy instruments can also spur innovation in a way that makes companies able to convert waste products into saleable goods to their evident economic advantage (Porter&van der linde, 1995:100-102). Basically, all three arguments rest on the assumption that 'emissions are a sign of inefficiencies and force the firm to perform non-value-creating activities such as handling, storage and disposal' (Porter&van der Linde, 1995:105).

The Porter hypothesis does not stand uncontested. Palmer, Oates and Portney disagree with the assumption concerning companies' failure to detect and realize the private economic benefits involved with improving environmental performance. According to Palmer et. al. private enterprises do not generally speaking systematically overlook profitable opportunities for innovation and production changes. If there is money to save and additional profit to make, private enterprises will recognize this opportunity. Here it is ascertained that private enterprises will basically always try to maximize profit with or without regulation. The cost-benefit literature does state that regulation may make sense from a socioeconomic perspective because the benefits from regulation, in the form of reduced pollution, reduced pressure on the environment and reduced health effects, outweigh the economic costs arising from the various policy instruments. However, Palmer et al. (1995:119-120) maintain that regulation will usually constitute an additional economic burden for private enterprises although they do not entirely dismiss instances where regulation has brought about partial or full offsets.

1.1.1 Energy efficiency improvements and carbon-energy tax burdens at the sub-sectoral level

The present analysis focuses on carbon-energy taxation as a regulatory tool to secure more efficient energy consumption. We would expect to observe declining trends with regard to energy intensity (GJ per output) in enterprises facing carbon-energy taxation.

Box 1 Energy cost changes induced by carbon-energy taxation

$$\Delta energy\_cost_{t1 \rightarrow tx} = \Delta S_{t1 \rightarrow tx} - \Delta C_{t1 \rightarrow tx}$$

$$\Delta S_{t1 \rightarrow tx} = (((GJ_{t1} / P_{t1}) - (GJ_{tx} / P_{tx})) * P_{tx}) * EP_{tx}$$

$$\Delta C_{t1 \rightarrow tx} = GJ_{tx} * (ET_{tx} - ET_{t1})$$

Energy (GJ) per production unit (P), where production unit or output is calculated by converting the value of output in each sector into constant year 2000 prices/values (deflating with the producer price index of each sector). This value has then been converted into euros.
Time period 1 (t1) is one year before the regulation is introduced. In the situation where data is not available for the year before introduction of the regulation, the earliest year with data will be used as t1. Time period 2 (tx) (x years after t1).
(EP) average energy price per GJ. Energy prices are measured in constant 2000 Euro prices.
(ET) average energy tax per GJ. Energy taxes are measured in constant 2000 Euro prices.

This method represents a simplified and initial depiction of Porter effects. Small changes in output caused by variation in demand can affect energy intensity. Additionally, ongoing autonomous technological development which improves energy intensity can be expected in most industrial sectors. Several other variables should be included in a more full analysis of the Porter effects, but as a first assessment we here explore whether the costs imposed by environmental taxation can be offset by the gains accomplished in energy efficiency.

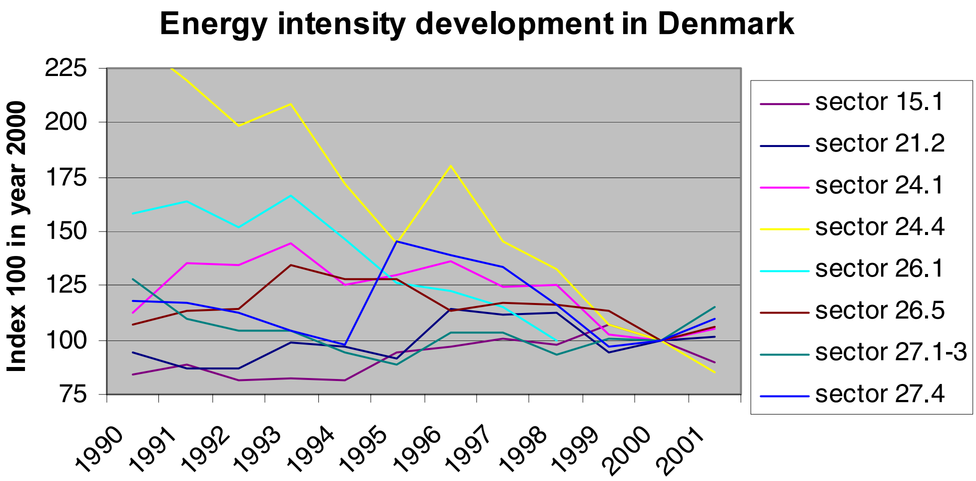
Environmental tax reform involves carbon-energy taxation but also a recycling mechanism for the revenues generated The purpose of revenue recycling is to minimize the economic burden for industry. As the tax is included in the assessment here, while revenue recycling is not, the economic burden imposed on the industry by ETR is by definition exaggerated. The following sections include descriptions of the revenue recycling mechanisms when data availability allows. For a more complete assessment, but with less sector details, the reader is referred to the results of WP6

The following exploration of the relationship between policy instruments and possible 'offsets' proceeds in two steps. First, trends in sectoral energy intensities and in carbon-energy tax burdens are analysed. Second, the balance of gross energy savings as compared to the tax burden will be analysed.

2 Denmark

Figure 2.1 displays the development in energy intensities in the eight Danish sub-sectors. The figure shows significant differences in energy intensity trends between the sectors.

Figure 2.1 Energy intensity index (based on GJ per unit of output) in eight Danish sub-sectors



From 1996, the year of ETR with impact on industry, most sectors have decreased energy input in relation to output. In several of the sectors, see for example sector 24.4 (pharmaceuticals), 26.1 (glass and glass products) and 26.5 (cement, lime and plaster), a notable change in the trends can be observed in 1996.

Table 2.1 Danish energy intensity (GJ per 1000 Euro output[1])

Million Euro	15.1	21.2	24.1	24.4	26.1	26.5	27.1-3	27.4
	Meat and meat products	Paper and paper products	Basic chemicals	Pharma-ceuticals	Glass and glass products	Cement, lime and plaster	Ferrous metals	Non-ferrous metals
1990	0.920	1.700	5.072	2.132	4.860	53.628	6.029	1.415
1991	0.965	1.553	6.084	1.962	5.040	57.101	5.170	1.412
1992	0.890	1.568	6.041	1.774	4.669	57.301	4.914	1.357
1993	0.894	1.769	6.517	1.866	5.114	67.305	4.899	1.254
1994	0.893	1.741	5.654	1.539	4.491	64.438	4.435	1.179
1995	1.029	1.641	5.841	1.294	3.885	64.359	4.172	1.754
1996	1.061	2.061	6.117	1.612	3.763	56.874	4.874	1.668
1997	1.097	2.003	5.585	1.297	3.541	58.805	4.884	1.603
1998	1.071	2.013	5.645	1.183	3.078	58.527	4.413	1.392
1999	1.168	1.688	4.622	0.961	3.773	57.052	4.739	1.165
2000	1.092	1.796	4.502	0.894	5.921	50.198	4.715	1.202
2001	0.983	1.822	4.725	0.762	6.110	53.179	5.421	1.323

[1] Output has been deflated with producer price index and converted to constant year-2000 Euro prices

In Denmark, carbon-energy taxation varies across sectors according to level of energy consumption, production processes in use, and voluntary agreements in place (Speck,2006). Table 2.2 shows the differences in the carbon-energy tax burden in the eight Danish sub-sectors. The figures show that the burden varies between the different sectors by a factor of more than 10. These figures therefore indicate significant differences in the incentives facing the companies.

Table 2.2 Danish energy tax burden (tax in Euro per GJ)[1]

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharmaceuticals	26.1 Glass and glass products	26.5[2] Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0
1992	0.332	0.073	0.277	0.096	0.061	0	0.046	0.351
1993	0.658	0.129	0.550	0.157	0.094	0	0.040	0.692
1994	0.583	0.085	0.498	0.116	0.062	0	-0.004	0.636
1995	0.518	0.028	0.417	0.067	0.029	0	-0.074	0.588
1996	0.914	0.360	0.320	0.545	0.387	0.101	0.222	0.594
1997	1.065	0.441	0.337	0.638	0.469	0.138	0.143	0.709
1998	1.237	0.548	0.378	0.700	0.504	0.206	0.174	0.861
1999	1.498	0.748	0.482	0.993	0.655	0.151	0.613	1.173
2000	1.687	0.759	0.633	1.299	0.763	0.079	0.655	1.475
2001	1.750	0.792	0.659	1.417	0.830	0.058	0.770	1.667

[1] Tax values have been deflated with GDP deflator and converted to constant year-2000 Euro prices

[2] For the years 1992-1995 the cement industry was refunded all CO2 taxes above DKK 10,000

Table 2.3 shows the ETR tax burden against the gross energy efficiency savings, as well as the net effect. The costs and savings have been calculated according to the method described in Box 1. Table 2.4 provides net results for all sectors.

Table 2.3 Tax burden and energy savings in three Danish sectors

Million Euro	15.1 Meat and meat products			24.1 Pharmaceuticals			26.5 Cement, Lime and Plaster		
	Savings	Tax	Total	Savings	Tax	Total	Savings	Tax	Total
1990									
1991[1]									
1992	3.99	1.74	2.26	0.26	1.39	-1.13	-0.13	0.0	-0.13
1993	3.69	3.54	0.15	-2.52	2.93	-5.45	-5.44	0.0	-5.44
1994	3.88	3.19	0.68	3.18	2.66	0.52	-4.67	0.0	-4.67
1995	-3.10	2.87	-5.97	1.63	2.39	-0.76	-5.15	0.0	-5.15
1996	-4.30	4.97	-9.27	-0.24	1.85	-2.09	0.19	1.92	-1.73
1997	-5.87	5.88	-11.75	4.06	2.03	2.03	-1.56	2.65	-4.21
1998	-4.78	7.10	-11.88	3.12	2.08	1.04	-1.13	3.85	-4.99
1999	-8.18	8.96	-17.15	10.82	2.31	8.51	0.03	2.74	-2.70
2000	-5.97	9.43	-15.40	12.55	3.10	9.45	4.48	1.38	3.10
2001	-0.95	9.08	-10.03	12.55	3.25	9.30	3.11	1.01	2.10

[1] Time period 1 (t1) has been set at 1991 (see Box 1 for further explanation)

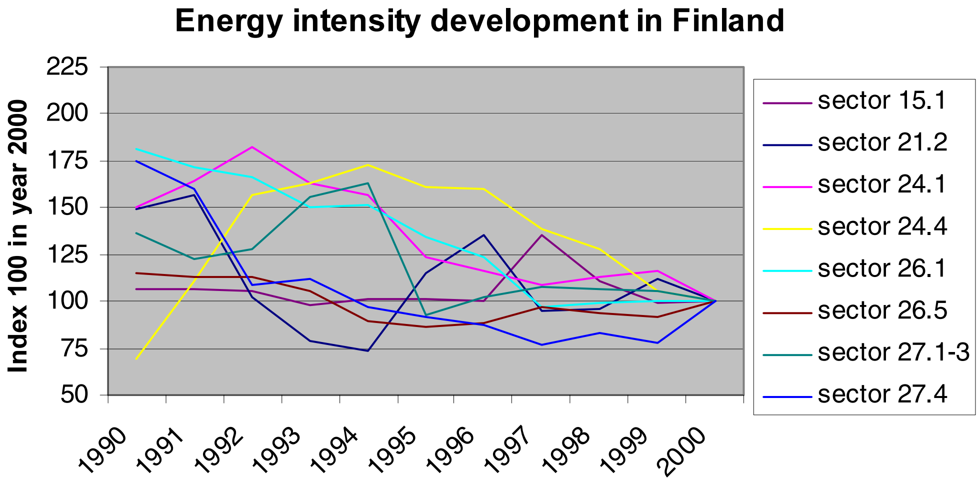
Table 2.4 Net gain or loss from energy savings and tax burden (without revenue recycling) (Denmark)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992	2,256	-0,167	-1,127	2,139	0,971	-	1,208	0,071
1993	0,154	-0,316	-5,453	0,748	-0,387	-	1,245	0,388
1994	0,685	-0,751	0,522	5,991	1,483	-	4,680	0,829
1995	-5,973	-0,643	-0,759	9,779	4,350	-	7,954	-1,390
1996	-9,273	-2,698	-2,093	3,569	3,956	-1,727	1,379	-1,118
1997	-11,751	-2,475	2,030	11,092	5,225	-4,208	1,694	-1,030
1998	-11,881	-2,473	1,036	15,705	8,604	-4,986	4,898	-0,369
1999	-17,147	-2,620	8,510	27,354	3,351	-2,705	0,018	0,339
2000	-15,399	-2,767	9,448	32,265	-4,195	3,097	0,108	0,040
2001	-10,026	-4,060	9,299	49,428	-5,181	2,102	-4,449	-0,523

3 Finland

The Finnish CO_2 tax was introduced in 1990 but with a very modest tax rate. The Finnish scheme was reformed in 1997 with substantial increases of the tax burden (Speck 2006). Figure 3.1 displays the development in energy intensity in the eight Finnish sub-sectors. The chart shows a downward trend, and hence a decrease in energy consumption per unit of output, in almost all sectors (see note to Figure 3.1 for a description of the situation for sector 24.4). Only sectors 15.1 (meat and meat products) and 26.5 (cement, lime and plaster) do not display a predominantly downward trend.

Figure 3.1 Energy intensity index (based on GJ per unit of output) in eight Finnish sub-sectors



Note The energy intensity increase in sector 24.4 (pharmaceuticals) between 1990 and 1992 could be due to definition changes associated with heat consumption.

Table 3.1 shows great variation in energy intensity across the eight COMETR sectors. Sector 15.1 (meat and meat products) displays the lowest energy consumption per output.

Table 3.1 Finland energy intensity (GJ per 1000 Euro output)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990	1.30	2.74	21.09	1.29	13.56	55.43	25.82	8.18
1991	1.31	2.88	23.11	2.07	12.87	54.22	23.27	7.48
1992	1.28	1.87	25.69	2.95	12.51	54.51	24.28	5.05
1993	1.20	1.44	22.86	3.06	11.31	50.99	29.39	5.21
1994	1.24	1.35	22.04	3.23	11.35	43.13	30.93	4.53
1995	1.24	2.11	17.42	3.03	10.05	41.52	17.47	4.28
1996	1.22	2.49	16.27	3.00	9.26	42.69	19.30	4.08
1997	1.66	1.73	15.22	2.61	7.27	46.51	20.29	3.56
1998	1.36	1.77	15.83	2.40	7.43	45.28	20.09	3.87
1999	1.21	2.05	16.31	1.99	7.52	44.19	20.03	3.62
2000	1.22	1.83	14.06	1.88	7.51	48.14	18.92	4.66

Also the carbon-energy tax burden varies across the eight sectors in Finland. However, Table 3.2 reveals that the differences across sectors are much smaller compared with those in Denmark. The variation in the carbon-energy tax burden in Finland is mainly caused by differences in the energy mix. Each company and each sector uses a unique mix of energy products, and since the tax levels of the various energy products are based on both energy content and CO_2 content, the tax level per average energy unit varies across the eight sectors. The increase in the tax levels after the 1994 and 1997 tax reforms should be noted.

Table 3.2 Finland carbon-energy tax burden (tax in Euro per GJ)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharmaceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990	0.06	0.03	0.07	0.04	0.06	0.14	0.12	0.06
1991	0.05	0.03	0.07	0.06	0.06	0.14	0.12	0.06
1992	0.04	0.02	0.06	0.04	0.05	0.12	0.10	0.04
1993	0.13	0.05	0.12	0.11	0.09	0.20	0.21	0.09
1994	0.21	0.11	0.22	0.20	0.24	0.43	0.41	0.15
1995	0.35	0.14	0.34	0.32	0.24	0.76	0.67	0.20
1996	0.30	0.13	0.33	0.29	0.24	0.71	0.66	0.19
1997	0.69	0.41	0.65	0.50	0.57	1.16	0.97	0.83
1998	0.91	0.46	0.77	0.51	0.62	0.39	0.40	0.92
1999	1.07	0.56	0.74	0.59	0.77	0.32	0.69	1.16
2000	1.04	0.54	0.69	0.56	0.74	0.31	0.47	1.03

Figure 3.1 above revealed that the majority of the Finnish sectors were able to improve energy intensity in the period from 1990 to 2000. Table 3.3 and 3.4 below show the total economic effect of the taxation for all eight sub-sectors. The total economic effect is predominantly positive for the Finnish sectors.

Table 3.3 Tax burden and energy savings in three Finnish sectors

Million Euro	15.1 Meat and meat products			24.1 Pharmaceuticals			26.5 Cement, lime and plaster		
	Savings	Tax	Total	Savings	Tax	Total	Savings	Tax	Total
1990									
1991	-0,18	-0,01	-0,17	-21,42	0,00	-21,42	0,45	0,01	0,44
1992	0,22	-0,03	0,25	-46,53	-0,38	-46,14	0,30	-0,11	0,41
1993	1,74	0,18	1,57	-21,90	2,36	-24,26	1,29	0,30	0,99
1994	0,94	0,36	0,57	-12,86	7,23	-20,10	3,94	1,29	2,65
1995	0,98	0,69	0,28	63,51	13,03	50,48	4,57	2,90	1,67
1996	1,55	0,64	0,90	90,75	11,83	78,92	5,11	2,88	2,23
1997	-6,82	2,26	-9,08	118,77	27,47	91,29	3,43	5,73	-2,30
1998	-1,08	2,47	-3,55	95,10	34,10	61,00	3,61	1,39	2,22
1999	1,59	2,77	-1,18	92,99	35,26	57,73	4,60	1,08	3,52
2000	1,41	2,63	-1,22	160,51	31,28	129,23	2,91	1,05	1,86

In the first part of the observed time period sector 24.1 displays a negative result. However, after the tax reform in 1994 the energy efficiency is improved and savings are realized causing the total economic effect to become positive.

When looking at the general economic effect across all eight Finnish subsectors a negative economic effect of the taxation can only be detected in sectors 15.1 (meat and meat products) and 24.4 (pharmaceuticals). Both sectors can be characterized as sectors with low energy intensity, which may help explain why these sectors have not improved their energy intensity.

Table 3.4 Net gain or loss from energy savings and tax burden (Finland)

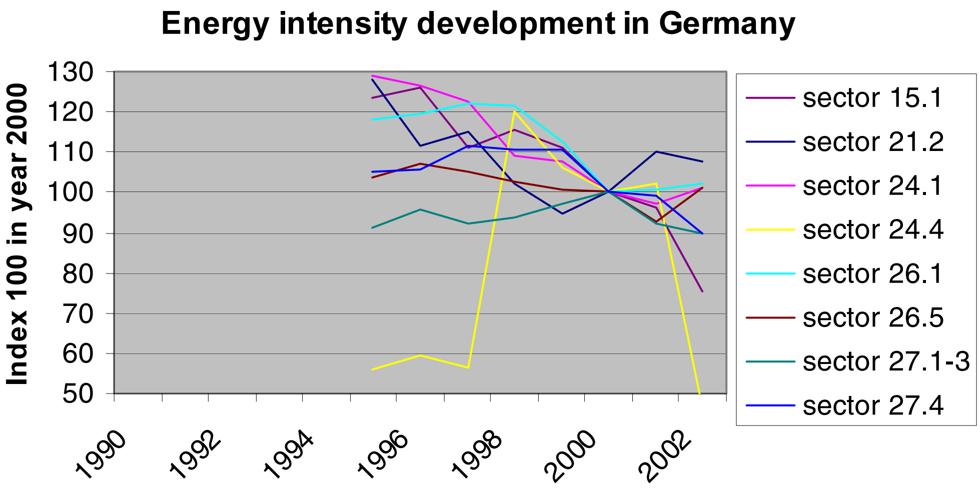
Million Euro	15.1	21.2	24.1	24.4	26.1	26.5	27.1-3	27.4
1990								
1991	-0.173	0.945	-21.419	-2.192	1.062	0.438	26.264	7.172
1992	0.254	6.065	-46.144	-4.927	1.796	0.412	16.548	41.635
1993	1.565	6.325	-24.256	-4.993	4.279	0.990	-44.171	40.461
1994	0.573	7.152	-20.097	-5.759	3.691	2.654	-63.301	54.351
1995	0.283	7.875	50.479	-5.695	7.448	1.669	101.645	59.128
1996	0.903	2.719	78.920	-6.132	10.832	2.226	75.046	76.077
1997	-9.079	6.395	91.293	-5.012	15.583	-2.298	42.084	80.061
1998	-3.548	5.644	61.002	-4.975	15.110	2.222	63.564	72.423
1999	-1.179	6.865	57.725	-3.491	14.394	3.521	44.286	80.176
2000	-1.216	8.033	129.225	-3.421	15.506	1.860	105.964	50.947

Based on data compiled in COMETR

4 Germany

In Germany an environmental tax reform was introduced in 1999. However, German industry had been subject to various forms of energy taxation for a number of years. Table 4.1 shows that the carbon-energy tax burden in most sectors approximately doubled after 1999. Figure 4.1 shows that a decreasing trend in energy intensity can be observed in the majority of the eight German sub-sectors.

Figure 4.1 Energy intensity index (based on GJ per unit of output) in eight German sub-sectors



Based on data compiled in COMETR

Note The energy intensity volatility in sector 24.4 (pharmaceuticals) in 1998 and 2002 could be caused by problems with German nomenclature.

Figure 4.1 shows that over the entire period, 1995-2002, energy intensity increases slightly in sector 27.1-3 (ferrous metals), while in sector 26.5 (cement, lime and plaster) it is almost stable for the entire period. sectors 26.5 (cement, lime and plaster) and 27.1-3 (ferrous metals) are by far the most energy-intensive German industries. Table 4.1 below shows how the energy intensities in these two industries are more than twice as high as for the sector which lies third.

Table 4.1 German energy intensity (GJ per 1000 Euro output)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993								
1994								
1995	1.81	2.48	9.86	0.85	11.03	41.95	19.49	4.91
1996	1.84	2.17	9.68	0.90	11.16	43.29	20.40	4.94
1997	1.62	2.24	9.40	0.86	11.42	42.52	19.63	5.23
1998	1.69	1.99	8.37	1.83	11.34	41.53	19.94	5.18
1999	1.62	1.84	8.22	1.61	10.52	40.70	20.76	5.18
2000	1.46	1.94	7.66	1.52	9.34	40.42	21.32	4.68
2001	1.41	2.13	7.45	1.55	9.39	37.48	19.64	4.65
2002	1.10	2.09	7.74	0.71	9.53	40.83	19.17	4.20

Based on calculation of data compiled in COMETR

The figures in Table 4.2 show that sector 26.5 (cement, lime and plaster) and 27.1-3 (ferrous metals) differ from the other six sectors regarding the level of the taxation. The carbon-energy tax burden, in Euro per GJ, levied on sectors 26.5 (cement, lime and plaster) and 27.1-3 (ferrous metals) is less than half of the burden on any other of the German sub-sectors studied in COMETR. This could indicate that the level of the energy tax for sectors 26.5 (cement, lime and plaster) and 27.1-3 (ferrous metals) was set too low to create a real impact, considering the energy intensity and the energy technology applied in these sectors.

Table 4.2 Germany carbon-energy tax burden (tax in Euro per GJ)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass prod-ucts	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993								
1994								
1995	0.787	0.993	0.595	0.856	0.678	0.264	0.345	1.229
1996	0.394	0.405	0.143	0.386	0.371	0.079	0.128	0.203
1997	0.377	0.405	0.164	0.369	0.355	0.073	0.122	0.214
1998	0.362	0.379	0.172	0.315	0.356	0.081	0.122	0.205
1999	0.549	0.629	0.360	0.534	0.498	0.158	0.213	0.557
2000	0.604	0.686	0.428	0.565	0.545	0.169	0.219	0.663
2001	0.623	0.725	0.482	0.591	0.553	0.196	0.242	0.735
2002	0.764	0.764	0.540	0.698	0.561	0.210	0.264	0.803

Based on data compiled in COMETR

A further exploration of the effect of energy-related policy instruments using the 'taxation-induced energy cost change' method described in Box

1 supports the results described in the previous sections. Table 4.4 below lists the total economic effect of the carbon-energy taxation. The table for Germany shows that only three sectors display a negative offset following the ETR reform in 1999.

Table 4.3 Tax burden and energy savings in three German sectors

Million Euro	15.1			21.2			26.5		
	Meat and meat products			Paper and paper products			Cement, lime and plaster		
	Savings	Costs	Total	Savings	Costs	Total	Savings	Costs	Total
1990									
1991									
1992									
1993									
1994									
1995									
1996									
1997									
1998									
1999	10.21	5.88	4.33	-3.40	7.99	-11.39	9.45	10.59	-1.14
2000	40.01	7.23	32.78	-26.56	10.58	-37.14	12.46	11.55	0.91
2001	52.37	7.38	45.00	-44.25	12.36	-56.61	55.92	12.84	43.08
2002	115.57	9.21	106.36	-46.07	13.67	-59.75	7.06	13.32	-6.26

Based on data compiled in COMETR

Table 4.4 Net gain or loss from energy savings and tax burden (without revenue recycling) (Germany)

Million Euro	15.1	21.2	24.1	24.4	26.1	26.5	27.1-3	27.4
	Meat and meat products	Paper and paper products	Basic chemicals	Pharma-ceuticals	Glass and glass products	Cement, lime and plaster	Ferrous metals	Non-ferrous metals
1990								
1991								
1992								
1993								
1994								
1995								
1996								
1997								
1998								
1999	4.33	-11.39	-35.25	26.04	21.18	-1.14	-145.83	-33.72
2000	32.78	-37.14	206.70	41.17	87.53	0.91	-225.87	47.85
2001	45.00	-56.61	315.82	36.12	96.70	43.08	-37.51	53.80
2002	106.36	-59.75	140.11	211.38	78.73	-6.26	12.43	162.96

Based on data compiled in COMETR

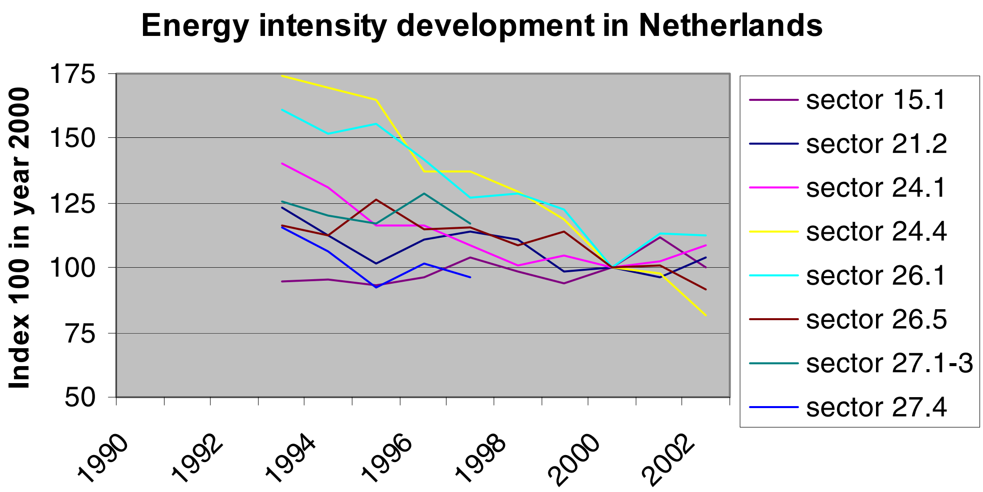
The revenue recycling mechanism in Germany is an important additional factor that has to be taken into consideration. Recycling the tax revenues back to the industries decreases the economic burden of the taxation scheme. The recycling mechanism will therefore reduce the negative economic effect of the tax reform in sector 21.2 (paper and paper products) and 27.1-3 (ferrous metals) and further increase the positive economic effect in the other 6 COMETR sub-sectors. The net impact, taking revenue recycling into consideration, is explored in WP6.

5 Netherlands

The Netherlands introduced carbon-energy taxation at a relatively early stage. During the entire period observed in the analysis, Dutch industries have been charged with various forms of energy taxation. However, a genuine ETR with revenue recycling was not introduced in the Netherlands until 1998/1999.

Figure 5.1 below shows the development in energy intensity in the Netherlands for the eight COMETR sub-sectors. It is apparent from the figure that most of the Dutch sectors have improved energy intensity significantly during the period observed. See the note to Figure 5.1 [note missing] for an explanation of the trends in sectors 15.1 (meat and meat products) and 21.2 (paper and paper products).

Figure 5.1 Energy intensity index (based on GJ per unit of output) in eight Dutch sub-sectors



Based on the data compiled in COMETR

Despite the favourable trends in energy intensity in each of the various sectors in the Netherlands, the Dutch sectors still display large differences with regard to absolute levels of energy intensity. Table 5.1 below illustrates the situation.

Table 5.1 Dutch energy intensity (GJ per 1000 euro output)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993	0.67	2.05	12.29	2.73	14.77	6.95	43.57	13.22
1994	0.68	1.87	11.47	2.66	13.95	6.71	41.50	12.14
1995	0.66	1.69	10.19	2.59	14.30	7.55	40.58	10.57
1996	0.69	1.85	10.18	2.15	12.99	6.86	44.61	11.66
1997	0.74	1.90	9.52	2.15	11.69	6.90	40.47	11.01
1998	0.70	1.84	8.86	2.03	11.79	6.49	40.67	10.85
1999	0.67	1.64	9.17	1.86	11.20	6.81	34.32	10.48
2000	0.71	1.66	8.77	1.57	9.16	5.97	34.59	11.44
2001	0.80	1.60	8.96	1.54	10.40	6.04		
2002	0.71	1.72	9.53	1.28	10.28	5.45		

Based on data compiled in COMETR

Just as in the other countries covered in this study, the carbon-energy tax burden varies significantly across the eight sub-sectors.

Table 5.2 Dutch carbon-energy tax burden (tax in euro per GJ)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993	0.23	0.22	0.34	0.30	0.36	0.37	0.55	0.06
1994	0.22	0.22	0.33	0.29	0.35	0.36	0.54	0.07
1995	0.22	0.22	0.34	0.30	0.36	0.37	0.56	0.08
1996	0.33	0.30	0.34	0.31	0.35	0.38	0.54	0.07
1997	0.40	0.36	0.32	0.31	0.31	0.38	0.50	0.08
1998	0.46	0.44	0.33	0.31	0.32	0.38	0.50	0.07
1999	0.65	0.64	0.35	0.46	0.37	0.46	0.50	0.08
2000	0.84	0.82	0.34	0.61	0.39	0.56	0.47	0.10
2001	1.27	1.23	0.38	0.89	0.54	0.82	0.48	0.15
2002	1.28	1.28	0.39	0.93	0.54	0.84	0.47	0.15

Based on the database compiled in COMETR

Despite the large differences in the energy intensity and tax burden, the analysis of the eight Dutch sectors shows that most of the sectors have actually managed to decrease their relative energy expenditure following the introduction of energy taxation. Table 5.3 below shows that the introduction of carbon-energy taxation has only caused additional economic burden in sector 15.1 (meat and meat products), which is the sector with the lowest overall energy intensity of the eight Dutch sectors examined.

Table 5.3 Net gain or loss from energy savings and tax burden (Netherlands)

Million euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993								
1994	-0.45		55.34	2.60	2.98	1.35	11.85	12.38
1995	0.95		153.74	5.63	1.67	-3.16	14.64	35.82
1996	-1.57		164.56	22.28	7.36	0.42	-4.40	19.75
1997	-7.00		235.93	26.29	15.09	0.20	23.08	31.04
1998	-4.23		287.57	30.97	14.40	2.84	23.04	35.96
1999	-2.49		241.91	35.73	16.49	0.16	58.97	43.32
2000	-7.84		397.51	66.03	38.82	6.23	73.98	33.45
2001	-16.63		367.87	63.70	22.56	2.85		
2002	-9.46		273.66	87.06	22.61	6.41		

Based on the database compiled in COMETR

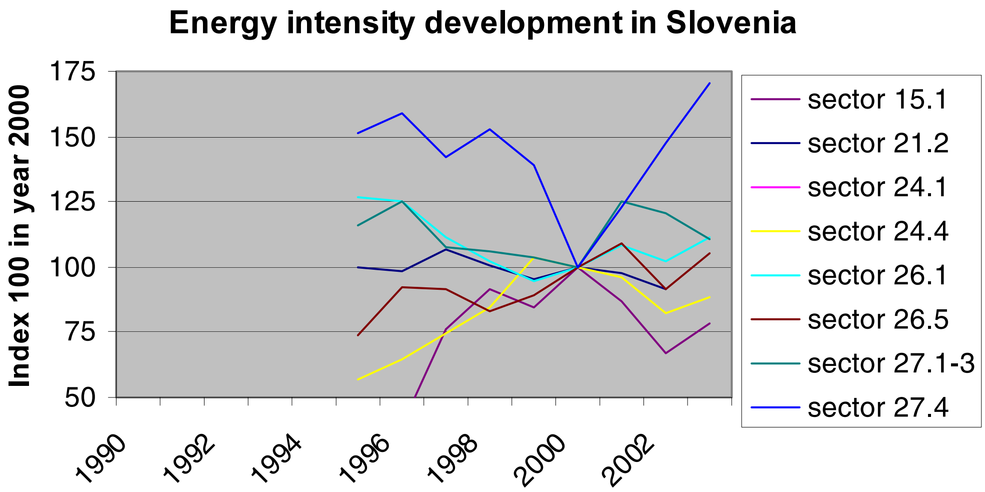
The revenue recycling mechanism in the Netherlands further supports the positive effects of the environmental tax reform. Recycling the tax revenues back to industry decreases the economic burden of the taxation scheme. Precise figures for the total economic effect of the recycling mechanism in the Netherlands are difficult to estimate. Green tax revenues have been recycled back to the industries in the form of a percentage reduction in the corporate tax and a percentage reduction in the employers' contributions to the national healthcare system. This revenue recycling further reduces the negative economic impact of the green taxation schemes on the industrial sectors studied.

6 Slovenia

The Slovenian case is the weakest case of the seven COMETR countries with regard to data reliability and consistency. Several anomalies have been detected in the Slovenian data which remain unexplained. A number of these will be the product of real changes caused by the fact that Slovenia was going through a transition period during the 1990s. However, it is also suspected that some of the anomalies are caused by developments in the data collection methods used in the statistical bureaus in Slovenia.

For the period from 1995 to 2000, Figure 6.1 below shows a general downward trend in energy intensity only for three energy-intensive sectors 26.1 (glass and glass products), 27.1-3 (ferrous metals) and 27.4 (non-ferrous metals). Between 2000 and 2003, however, energy intensity increased in these sectors; although the increase appears abrupt. Sector 21.2 (paper and paper products) displays a stable but slightly decreasing energy intensity. The remaining sectors, i.e. the very energy-intensive sector 26.5 (cement, lime and plaster) and the two low energy-intensive sectors 15.1 (meat and meat products) and 24.4 (pharmaceuticals) all display a general increase in energy intensity over the observed period. Changes in energy efficiency or energy intensity, however, depend on factors other than carbon-energy taxation. The status of Slovenia as a transition country with a rapidly changing economy has without doubt been a major factor affecting the development of many of the industrial sectors in the country, and the impact of carbon-energy taxation on energy efficiency may have been clouded.

Figure 6.1 Energy intensity index (based on GJ per unit of output) in eight Slovenian sub-sectors



Based on data compiled in COMETR

Table 6.1 Slovenian energy intensity (GJ per 1000 Euro output)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993								
1994								
1995	1.15	4.95		1.16	15.66	39.65	18.79	30.26
1996	1.05	4.86		1.31	15.46	49.41	20.27	31.87
1997	2.02	5.28		1.52	13.74	49.10	17.37	28.45
1998	2.42	4.98		1.73	12.64	44.57	17.13	30.61
1999	2.25	4.70		2.11	11.64	47.89	16.82	27.77
2000	2.65	4.94		2.04	12.34	53.57	16.17	20.02
2001	2.30	4.84		1.97	13.38	58.30	20.22	24.55
2002	1.78	4.50		1.69	12.63	48.77	19.53	29.53
2003	2.09			1.81	13.78	56.45	17.86	34.17

Based on data compiled in COMETR

There are only small variations in the tax burden experienced by the eight Slovenian sectors. Table 6.2 below displays the average carbon-energy tax level in the various Slovenian sectors. Only the tax rates in sectors 26.5 (cement, lime and plaster) and 27.4 (non-ferrous metals) deviate significantly from those in the other sectors.

Table 6.2 Slovenian carbon-energy tax burden (tax in Euro per GJ)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993								
1994								
1995								
1996								
1997	0.21	0.16	0.20	0.15	0.18	0.31	0.17	0.03
1998	0.61	0.46	0.53	0.39	0.48	0.83	0.45	0.09
1999	0.72	0.61	0.65	0.54	0.64	0.95	0.54	0.11
2000	0.80	0.58	0.60	0.51	0.62	0.88	0.50	0.11
2001	0.89	0.65	0.69	0.57	0.71	0.86	0.53	0.13
2002	0.81	0.60	0.61	0.51	0.64	0.85	0.49	0.09
2003	0.74	0.60	0.61	0.47	0.63	0.85	0.57	0.09

Based on data compiled in COMETR

The total economic effect of the carbon-energy taxation in the eight Slovenian sub-sectors analysed in COMETR can be found in Table 6.3 below. The table shows that sectors 21.2 (paper and paper products), 26.1

(glass and glass products) and 27.4 (non-ferrous metals) have experienced a general positive offset. Most sectors face a negative offset.

Table 6.3 Net gain or loss from energy savings and tax burden (Slovenia)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993								
1994								
1995								
1996	0.41	0.91	3.89	-0.87	0.14	-3.39	-3.24	-2.99
1997	-2.78	0.13	0.25	-2.40	1.31	-4.64	2.71	3.70
1998	-3.81	0.65	-1.62	-3.60	2.03	-5.13	1.70	-1.08
1999	-3.90	1.29	-2.05	-5.02	2.82	-6.93	1.73	4.61
2000	-5.32	1.26	-2.08	-5.18	2.22	-9.62	4.44	28.01
2001	-4.18	1.62	-4.61	-5.36	1.14	-10.82	-6.70	11.71
2002	-2.40	1.47	-4.18	-3.41	1.38	-5.70	-4.36	1.05
2003	-3.42	-0.52	-5.67	-4.47	0.32	-7.77	-1.55	-8.62

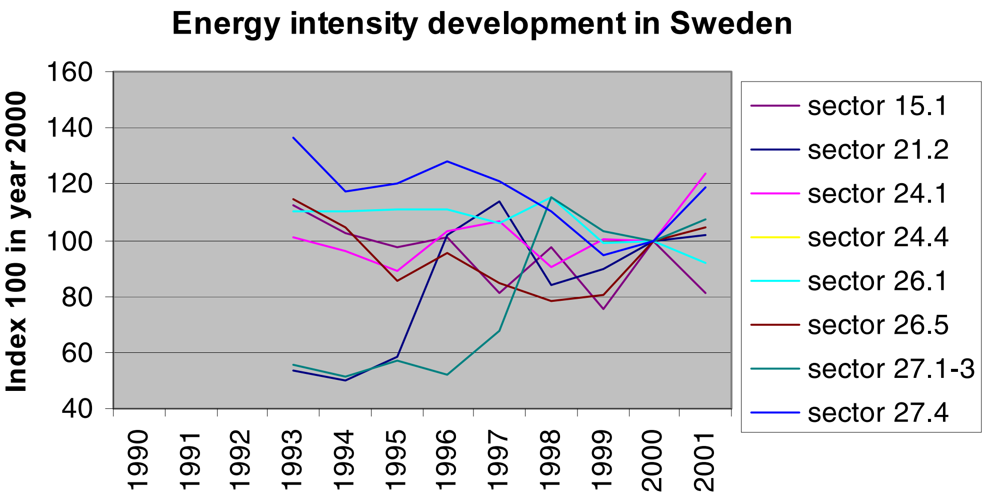
Based on data compiled in COMETR

7 Sweden

Various forms of carbon-energy taxes have been levied on Swedish industry over the entire period under observation. Sweden was also one of the first countries to gain experience with genuine ETR. Already in 1991/1992, Sweden introduced a tax reform that linked environmental taxation to revenue recycling in the form of lower personal income taxation.

Figure 7.1 below depicts the developments in energy intensity in the Swedish sub-sectors. Even when disregarding sector 21.2 (paper and paper products) and 27.1-3 (ferrous metals) (see note for the figure) the general trend is still somewhat mixed. Especially sectors 24.1 (basic chemicals) and 26.5 (cement, lime and plaster) can be characterized by their increasing energy intensity while sectors 27.4 (pharmaceuticals) and 26.1 (glass and glass products) can be characterized by their decreasing energy intensity.

Figure 7.1 Energy intensity index (based on GJ per unit of output) in eight Swedish sub-sectors



Based on data compiled in COMETR

Note the significant increase in the energy intensity in sector 21.2 (paper and paper products) and 27.1-3 (ferrous metals) in the time period from 1995 to 1998 could reflect a change in the calculation method or sector definitions more than a real change in the consumption.

Table 7.1 Swedish energy intensity (GJ per 1000 Euro output)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharmaceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993	1.16	1.19	5.80		8.17	55.63	6.88	9.85
1994	1.06	1.12	5.52		8.15	50.71	6.39	8.44
1995	1.01	1.31	5.13		8.20	41.51	7.09	8.65
1996	1.05	2.27	5.93		8.21	46.15	6.45	9.23
1997	0.84	2.54	6.14		7.87	41.23	8.37	8.71
1998	1.01	1.88	5.18		8.55	38.17	14.21	7.96
1999	0.78	2.01	5.76		7.33	39.10	12.74	6.80
2000	1.03	2.23	5.75		7.41	48.51	12.35	7.20
2001	0.84	2.28	7.10		6.83	50.87	13.31	8.57
2002	0.75	1.91	7.19		6.05	56.27	12.99	8.96

Based on data compiled in COMETR

The Swedish carbon-energy tax burden also varies across the sub-sectors. The most significant difference in tax burden in the Swedish sectors is not found across sectors but across time. As a result of general economic problems in Sweden in the 1990s and the competitiveness problems experienced by Swedish industry, it was decided to reduce carbon-energy taxation significantly in 1993. During the remainder of the period observed, carbon-energy taxation in Sweden does not reach the level of the early 1990s.

Table 7.2 Swedish carbon-energy tax burden (tax in Euro per GJ)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharmaceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990	2.40	1.40	2.14	1.44	1.36	0.65	0.58	0.32
1991	2.23	1.31	1.96	1.57	0.86	0.96	0.84	0.34
1992	2.14	1.38	1.85	1.71	0.78	0.94	0.79	0.33
1993	0.25	0.27	0.10	0.05	0.15	0.21	0.16	0.06
1994	0.22	0.28	0.13	0.08	0.15	0.20	0.16	0.05
1995	0.24	0.26	0.13	0.19	0.14	0.20	0.14	0.04
1996	0.26	0.22	0.13	0.20	0.21	0.21	0.17	0.05
1997	0.60	0.44	0.26	0.54	0.43	0.40	0.27	0.10
1998	0.49	0.46	0.21	0.37	0.40	0.39	0.26	0.13
1999	0.35	0.26	0.17	0.46	0.43	0.41	0.27	0.07
2000	0.53	0.24	0.23	0.23	0.73	0.36	0.27	0.14
2001	0.50	0.25	0.20	0.29	0.68	0.32	0.27	0.10
2002	0.38	0.22	0.21	0.19	0.69	0.33	0.27	0.08

Based on data compiled in COMETR

The reduction in energy taxation can be expected to have reduced the incentives to achieve more efficient consumption of energy and minimize the cost of the taxation. However, carbon-energy tax levels are still relatively high compared with several of the other countries analysed by COMETR. When looking at the total economic costs of carbon-energy taxation (see Table 7.3 below) it becomes apparent that most of the Swedish sectors, despite the high cost of the taxation, have been able to create positive offsets under the taxation scheme.

Table 7.3 Net gain or loss from energy savings and tax burden (Sweden)

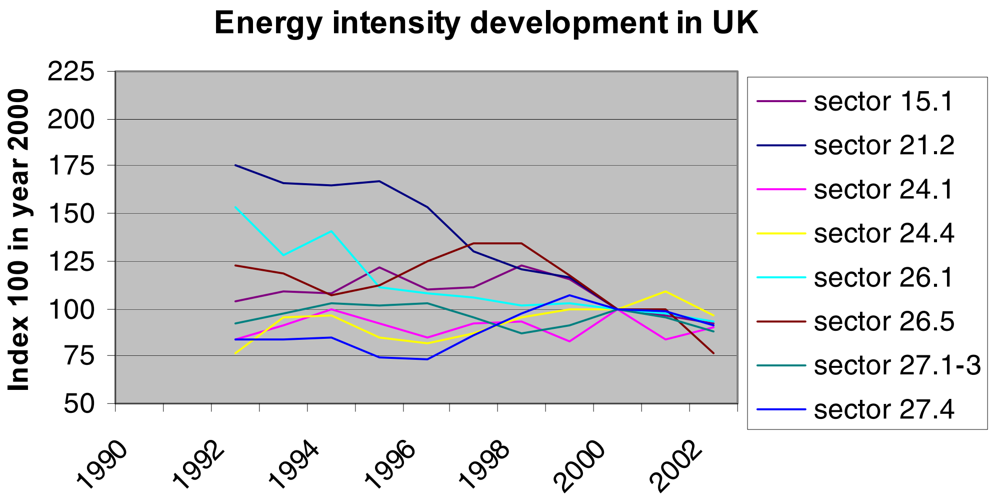
Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993								
1994	3.34		7.70	-3.13	0.07	3.13	22.03	14.92
1995	4.95		20.03	-0.17	-0.13	11.74	-9.00	11.01
1996	3.56		-4.36	0.04	-0.18	6.62	19.12	6.72
1997	6.93		-11.53	5.02	1.05	9.69	-48.98	11.33
1998	3.86		16.73	9.93	-1.44	13.43	-211.54	21.76
1999	9.99		-0.95	12.44	2.69	9.74	-176.92	40.01
2000	2.42		-2.09	4.09	2.96	3.32	-193.63	31.92
2001	10.24		-40.07	12.03	5.64	3.04	-215.55	12.07
2002	13.23		-42.32	15.39	9.49	-0.35	-220.26	8.65

Based on data compiled in COMETR

8 United Kingdom

The UK implemented the first purely environmental tax reform with the introduction of the climate change levy in 2001. The climate change levy was not the first energy tax levied on industry in the UK. A tax on energy consumption was levied on UK industry during the entire period observed in COMETR. Table 8.2 displays the developments in carbon-energy tax burden over the entire period observed. It is evident from the figures in the table that introduction of the climate change levy in 2001 marked a significant increase in the carbon-energy tax burden on UK industry. The tax burden more than doubled in all sectors as a result of the climate change levy. However, the tax levels had also changed significantly several times during the decade up to the turn of the century and the overall tax level had often been significantly higher in earlier years than in 2001 after the introduction of the climate change levy. In addition it should be noted that a significant difference in carbon-energy tax burden across the eight sub-sectors can be observed in Table 8.2.

Figure 8.1 Energy intensity in eight UK sub-sectors



Based on data compiled in COMETR

Figure 8.1 above shows developments in energy intensity in the UK. The graphs indicate that the industrial sectors have developed very differently over the period observed with regard to energy intensity. Over the ten-year period some sectors have decreased energy consumption per unit of output, in correspondence with Porter expectations, while other sectors have increased energy consumption. Although the climate change levy was not introduced until 2001, studies have shown that a change in behaviour in connection with the climate change levy could be measured already in 1999, two years before the actual introduction of the tax. This phenomenon has been labelled the 'announcement effect' (Agnolucci, Barker, Ekins, 2004).

Table 8.1 UK energy intensity (GJ per 1000 euro output)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992	1.23	2.24	12.34	1.26	7.76	25.68	19.96	4.84
1993	1.29	2.11	13.36	1.58	6.49	24.87	21.16	4.80
1994	1.28	2.10	14.60	1.61	7.10	22.47	22.23	4.87
1995	1.44	2.13	13.56	1.41	5.60	23.45	22.01	4.25
1996	1.30	1.96	12.54	1.35	5.48	26.12	22.12	4.24
1997	1.32	1.66	13.56	1.44	5.37	28.14	20.65	4.93
1998	1.46	1.54	13.79	1.59	5.12	28.11	18.89	5.62
1999	1.36	1.48	12.13	1.65	5.18	24.51	19.65	6.13
2000	1.19	1.27	14.72	1.66	5.06	20.95	21.65	5.76
2001	1.15	2.23	12.40	1.82	4.91	20.79	20.63	5.66
2002	1.09	2.10	13.29	1.60	4.70	15.95	18.96	5.24

Based on data compiled in COMETR

In particular two sectors, sector 24.4 (pharmaceuticals) and 27.4 (non-ferrous metals) show an increasing trend in energy intensity over the period observed in Figure 8.1. Sector 24.4 (pharmaceuticals) is characterized by low energy intensity, see Table 8.1, while sector 27.4 (non-ferrous metals), on the other hand, does not display low energy consumption per unit of output.

Table 8.2 UK carbon-energy tax burden (tax in Euro per GJ)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous Metals	27.4 Non-ferrous metals
1990	0.844	0.689	0.250	0.413	0.416	0.164	0.153	0.681
1991	1.075	0.897	0.322	0.573	0.528	0.215	0.194	0.789
1992	1.050	0.873	0.281	0.549	0.565	0.256	0.182	0.629
1993	0.999	0.939	0.271	0.507	0.585	0.257	0.174	0.708
1994	0.834	0.817	0.242	0.446	0.551	0.195	0.157	0.656
1995	0.743	0.784	0.265	0.472	0.570	0.207	0.180	0.641
1996	0.716	0.741	0.250	0.394	0.487	0.207	0.163	0.563
1997	0.230	0.324	0.105	0.100	0.216	0.054	0.106	0.188
1998	0.117	0.213	0.078	0.056	0.117	0.031	0.082	0.069
1999	0.170	0.119	0.042	0.021	0.233	0.015	0.080	0.076
2000	0.178	0.072	0.051	0.016	0.068	0.013	0.083	0.061
2001	0.502	0.438	0.189	0.247	0.309	0.234	0.174	0.234
2002	0.490	0.462	0.151	0.250	0.278	0.243	0.165	0.215

Based on data compiled in COMETR

In section 3.7.1 it was shown that trends in energy intensity differ across the eight UK sub-sectors. These differences may partly be explained by differences in the importance of energy input within the sectors, and associated managerial interest in improving energy efficiency.

A closer analysis including the energy savings (see Table 8.3 below) sheds further light on the situation. The three sectors in Table 8.3 give a good indication of the overall reason behind the lack of positive offset in the majority of the sectors. The table shows that the cost figures in all three sectors are not high. The other countries in this analysis display similar tax burdens and hence similar costs. The general negative offset is created by a lack of savings, a situation that changed when the climate change levy was announced and companies diverted focus towards efficiency in energy consumption.

Table 8.3 Tax burden and energy savings induced by carbon-energy taxation in three UK sectors

Million Euro	15.1			26.1			26.5		
	Meat and meat products			Glass and glass products			Cement, lime and plaster		
	Savings	Tax	Total	Savings	Tax	Total	Savings	Tax	Total
1990									
1991									
1992									
1993	-15.34	-1.05	-14.29	30.88	0.51	30.37	8.49	0.01	8.48
1994	-11.40	-4.73	-6.68	17.40	-0.41	17.82	33.88	-2.93	36.81
1995	-42.94	-7.74	-35.20	68.46	0.13	68.33	21.54	-2.33	23.87
1996	-16.24	-7.77	-8.47	64.73	-1.87	66.60	-3.51	-2.16	-1.35
1997	-19.67	-19.41	-0.27	64.05	-7.95	72.01	-16.43	-8.92	-7.51
1998	-45.60	-22.25	-23.35	69.98	-9.38	79.36	-16.87	-9.27	-7.60
1999	-24.11	-20.20	-3.90	68.56	-7.33	75.90	8.65	-9.27	17.92
2000	9.43	-19.18	28.61	82.08	-11.02	93.09	35.86	-8.56	44.42
2001	16.68	-11.32	28.00	86.83	-5.76	92.59	35.11	-0.76	35.88
2002	28.93	-11.20	40.13	93.49	-6.41	99.90	83.85	-0.42	84.26

Based on data compiled in COMETR

Altogether, the UK case has produced results that differentiate the UK from the remaining countries in this analysis. Whereas support for the Porter hypothesis can be found in most sectors in the other countries in this analysis, the UK case with its short time-span only shows a few results that can support the hypothesis about a positive economic offset induced by environmental policy instruments.

Table 8. Net gain or loss from energy savings and tax burden (without revenue recycling) (UK)

Million Euro	15.1 Meat and meat products	21.2 Paper and paper products	24.1 Basic chemicals	24.4 Pharma-ceuticals	26.1 Glass and glass products	26.5 Cement, lime and plaster	27.1-3 Ferrous metals	27.4 Non-ferrous metals
1990								
1991								
1992								
1993	-14.29	-2.05	-160.06	-42.28	30.37	8.48	-115.99	0.86
1994	-6.68	7.10	-324.90	-43.33	17.82	36.81	-203.34	-3.72
1995	-35.20	15.75	-181.28	-19.23	68.33	23.87	-194.10	57.03
1996	-8.47	125.46	-22.92	-8.51	66.60	-1.35	-208.92	57.13
1997	-0.27	191.51	-128.30	-12.62	72.01	-7.51	-45.88	11.98
1998	-23.35	259.43	-154.23	-33.71	79.36	-7.60	133.07	-29.54
1999	-3.90	300.76	113.82	-37.20	75.90	17.92	57.18	-55.21
2000	28.61	377.01	-282.47	-28.43	93.09	44.42	-108.40	-34.84
2001	28.00	193.74	19.15	-55.78	92.59	35.88	-47.73	-39.00
2002	40.13	259.88	-111.21	-33.62	99.90	84.26	70.71	-7.79

Based on data compiled in COMETR

Revenue recycling in the UK is an important additional factor that should be taken into consideration. In conjunction with the climate change levy in 2001 the UK government introduced a recycling mechanism to feed back the entire revenue from the climate change levy. In total between 330 and 860 million Euro has been recycled to the UK industry each year in the form of employers' tax contributions. Recycling the energy tax revenues back to industry decreases the economic burden of the taxation scheme. Precise figures for the total economic effect of the recycling mechanism for each of the eight sub-sectors are not possible to estimate with the available dataset. However, it can be concluded that the revenue recycled back to industry will reduce the negative economic impact of energy taxation on the industrial sectors covered in this analysis.

9 Some concluding observations

The paper has illustrated that the Porter hypothesis cannot be analysed from a static point of view. Environmental policy instruments do not represent a 'magic wand' that can spur a 'Porter effect' regardless of the type and implementation of the policy instrument, and regardless of the input and technological structure of the affected sectors. The impact point of the policy instruments can vary from sector to sector and numerous background variables need to be taken into consideration when analysing the economic effect of environmental policy instruments. The current analysis has examined the overall trends in the development of economic changes induced by carbon-energy taxation. Whether Porter effects have occurred and can be disentangled will be analyzed in a subsequent WP3-paper, presenting a panel-regression analysis, as well as in WP6, which addresses revenue-recycling and strategies for mitigation of competitiveness effects.

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The Impact of Energy Taxes on Competitiveness, Output and Exports: a panel regression study of 56 European industry sectors

WP3

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1 Introduction

The original Porter hypothesis states that high national environmental standards will encourage domestic industries to innovate and hence improve competitiveness, in particular when the regulatory standards anticipate requirements that will spread internationally (Porter, 1990; 1998). The main reason, according to Porter and van der Linde, is that environmental regulation puts a pressure on industry to innovate new and greener products that, in turn, create better demand conditions for the industry. Moreover, environmental standards encourage industries to find less resource intensive ways of production, thereby counteracting the initial rise in production costs caused by the regulatory demands. The earlier such regulatory pressures are introduced within a given country vis-à-vis other countries, the higher the chance that the innovative experiments arising from the pressure will lead to a competitive edge.[1]

The critics of the Porter hypothesis reject the argument that environmental regulation should lead firms down more profitable, innovative avenues. If such opportunities existed, they would have been pursued anyway by rational firms, and, in this light, the regulation is just another distortion that may hamper efficient allocation of resources. Hence, the controversy involves intriguing questions on economic rationality and institutional factors which are very difficult to answer *a priori*. This paper makes no attempt to resolve the theoretical question. It merely provides some empirical evidence that can be used to indicate if, and to what extent there is, a Porter effect in one special area of environmental regulation.

It is recognized that not all environmental regulation will have the desired effect. Porter agrees that traditional environmental regulations have often violated the principles for a positive impact on competitiveness by imposing rigid pollution abatement technologies, rather than leaving room for adaptation, flexibility and innovation (Porter, 1991). From this point of view, market-based environmental regulation, including environmental taxes, would be better suited to fulfil the Porter "prophecy". On the other hand, emission taxes (at least those without revenue recycling) introduce an out-of-pocket tax expense to the polluting firms on top of the extra abatement costs they experience from their attempts to reduce the tax burden. It brings us to the interesting question whether a Porter effect is in fact associated with environmental taxes and, if so, whether environmental taxes have better or worse effects on competition than environmental standards.

The focus of this paper is the extent to which energy taxes – via the resulting increase in real energy prices, or in their own right – reduce or enhance industrial competitiveness. From a panel data set covering 56 industry sectors throughout Europe over the period 1990-2003, we estimate how changes in real energy taxes and real energy prices affect, on the one hand, competitiveness measured in terms unit energy costs and

[1] Although, of course, if regulations are introduced too early, it may cause severe problems for industry thus hampering innovative efforts.

unit wage costs and, on the other hand, economic performance expressed in terms of output (value added) and exports. Accordingly, the paper distinguish between competitiveness as an economic potential, for example low unit energy costs, and the effects of that potential which, for example, could be higher economic output and exports. If the industries experience significantly lower exports and output as a consequence of a tax-imposed increase in real energy prices it is a clear indication that this outcome resulted because the energy taxes reduced their competitiveness. Such findings would give us reason to reject the Porter hypothesis in this specific case.

2 Modelling the Porter effects associated with energy taxes

A good theoretical model is required in order to estimate the causal subtleties associated with the possible Porter effect of an environmental tax on energy. According to economic theory, the effect of an energy tax will be exactly the same as the equivalent increase in energy prices. Energy price elasticities with respect to energy consumption and output has been extensively documented through a variety of statistical methods in the energy economics literature (for an overview see Atkinson and Manning, 1995, plus numerous articles in the Energy Economics journal).Panel regression and cointegration analyses have been more successful than older methods in capturing the long-term relation between energy prices and energy consumption. Typically the studies report long-term own-price elasticiticies of industrial energy consumption in the range between -0.3 and -0.6 (Barker et. al, 1995). This evidence tells us that energy taxes will have a strong environmental effect in the form of reduced energy consumption and hence less combustion of fossil fuels and lower emission of air pollution.

But what is the impact of energy taxes on competitiveness and economic performance? Energy is not just some environmental problem, but a major input factor into industrial production. Most evidence indicates that rising energy prices have an adverse impact on economic performance (Longva et. al, 1988; Smyth, 1993). The two oil crises during the 1970s speak for themselves (Nasseh and Elyasiani, 1984). Hence, it appears unlikely that energy taxes should be the carrier of a true Porter effect. Indeed, it is hard to believe that energy taxes will make room for so much innovation that it more than offsets the problem of rising input prices. But even if the net effect of an energy tax is a reduction in output, a mitigating Porter effect of substantial size may be involved.

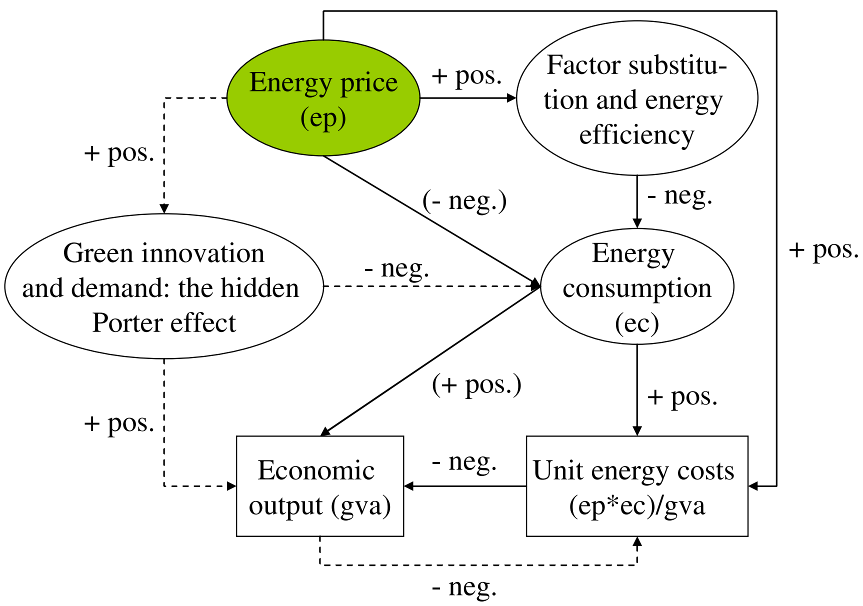

Figure 2.1 A causal model of the Porter effects

Figure 2.1 shows the basic reasoning. Variables that later appear as dependent variables in the analysis are indicated by rectangular boxes and variables that appear as independent variables, or unobserved intermediary causes, are indicated by oval boxes. A number of relevant independent variables are omitted from the figure, for example government regulation and subsidies to stimulate energy savings, the cost conditions of competitors, etc. The omitted factors are assumed to remain unaltered. There are two separate streams of influences, the first marked by solid lines and the other by dotted.

In the first stream, or chain of effects, the following logic applies. Rising taxes and energy prices will induce firms to substitution towards other input factors (mainly labour and capital) including energy efficiency improvements, which again will lead to lower energy consumption. If the possibilities for innovation and factor substitution are very limited, rising energy prices and taxes may even reduce output since lower energy consumption is not compensated for by other input factors (cf. the bracket relations) Factor substitution will, in turn, decrease unit energy costs. On balance, however, unit energy costs are expected to rise because of the higher energy price. The net impact is therefore a reduction in competitiveness on the assumption that competitors (especially foreign) do not experience a similar or higher increase in energy costs. The further implication of increasing unit energy costs (vis-á-vis competitors) is reduced economic output. Overall, the stronger the effect of the mitigating influences in the form of energy savings through factor substitution, the less negative impact on economic performance – and the more support to the supply-related elements of the Porter idea.

On the other hand, there is a second chain of effects in which rising energy prices and taxes may induce firms to product innovations that minimize the use of resources and other kinds of environmental initiatives that ensure more effective pollution abatement. This may, in turn, stimulate growth either because demand for the specific industrial products increase, or because the initiatives helps to create a strong green image, which improves the general economic conditions for the firm. This broader green innovation effect is the core of the Porter hypothesis, but it is much more difficult to observe and measure than the first chain of effects.

In the first chain of effects, the Porter element reduces to the mitigating influence that factor substitution has on the original negative economic impact of higher energy prices. One would never expect factor substitution to be so high that unit energy costs actually decline and output grows as a result of higher energy prices and taxes. However, the second chain of effects – the demand-related green innovation effect – introduces the possibility that, on balance, green energy taxes reduce competitiveness and output only slightly or perhaps even lead to improvements.

In the subsequent statistical analyses, we will test whether Porter hypotheses of various degrees are supported by the evidence relating to energy taxes. One of the most interesting questions is, of course, whether the hidden Porter effect is strong enough to offset the expected adverse impact of energy prices on economic performance. Hence, if we find a positive relation between energy taxes, competitiveness and output, it would indicate the existence of a *radical Porter effect*. This would indeed be contrary to ordinary economic reasoning and move the scope of the Porter hypothesis beyond its usual application to non-fiscal instruments of environmental regulation.

More likely, there is a chance that Porter effects working through the factor substitution channel and the demand-related innovation channel strongly reduce the original negative effects of energy taxes on unit energy costs and output. If that turns out to be the case, it will indicate the existence of a *mitigating Porter effect* even with respect to tax instruments of environmental regulation. Finally, if economic performance is severely harmed by rising energy prices and taxes as assumed by mainstream theory, it indicates the *absence of Porter effects* in this area.

3 Data and method

The analysis is based on the COMETR WP3 data set covering eight industrial sectors in seven different European countries for the period 1990-2003. This amounts to a maximum number of 784 observations on each variable. The countries included are Denmark, Finland, Germany, Netherlands, Slovenia, Sweden and the UK. The following sectors are included:

Table 3.1 The industry sectors in the WP3 data set

Sector (NACE 3-digit):
15.1 Meat industry
21.2 Paper and cardboard articles
24.1 Basic chemicals industry
24.4 Pharmaceuticals industry
26.1 Glass industry
26.5 Cement, lime and plaster
27.1-27.3 Basic ferrous metals
27.4 Basic Non-ferrous metals

Accordingly the data set contains a mixture of energy intensive (24.1, 26.1, 26.5, 27.1-3 and 27.4) and medium energy intensive sectors (15.1, 21.2 and 24.4). Data on a large number of energy-related and economic variables has been collected for each of the industry sectors by teams in the respective countries. Table 3.1 provides a list of the subset of variables that were included in the panel regressions. All economic variables are in fixed 2000 prices.

From the causal model in Figure 3.1, we note that endogeneity problems apply to the set of variables that, as a minimum, would be required to estimate both unit energy costs and economic output. Unit energy costs are influenced by economic output as economies of scale give rise to less energy use per unit when production increases and, in the other way around, economic output is influenced by unit energy costs as competitiveness influence the output level.

In deciding about the appropriate statistical methods to use for estimating the causal relations, we were limited by data availability. It was not feasible to extend the time series beyond the 14 year period 1990–2003. The relatively short time series ruled out the application of VAR and cointegration techniques, which would have been preferred (in combination with panel data techniques) given the challenge with endogeneous variables, the supposed dynamic character of the interrelations and the often reported cointegrating nature of the central variables (energy prices, energy consumption and output).[2]

[2] See, for example, Hunt and Manning (1989); Hunt and Lynk (1992); Bentzen and Engsted (1993); Barker et. al (1995); Asafu-Adjaye (2000); Stern (2000); Enevoldsen (2005, pp.187-220).

Table 3.2 List of variables applied in the panel regressions.

Variable	Description
gva	Gross value added (€ in fixed 2000 prices). Deflated by the producer price index (PPI)[3], GVA measures real economic output and is also used as a proxy measure of industrial production volume in economic terms
yvol	The value of total industrial output (€ in fixed 2000 prices).It is used as a proxy measure of industrial production volume in physical terms.
encon	Total energy consumption (GJ)
uec	Unit energy costs. Total energy costs (€) per value added (€). Total energy costs are divided by GVA
ulc	Unit labour costs. Labour costs (€) per value added (€). Total compensation of employees is divided by GVA.
urc	Unit raw materials costs. Total intermediate consumption (€) exclusive energy costs per value added (€).
uic	Unit input costs. Total factor input costs (€) per value added (€).
ep	Real energy price (€ in fixed 2000 prices). Total energy costs are divided by total energy consumption and thereafter deflated by PPI.
epex	Real energy price exclusive taxes (€ in fixed 2000 prices). Total energy costs exclusive taxes are divided by total energy consumption and thereafter deflated by PPI.
etax	Real energy taxes (€ in fixed 2000 prices). Total energy taxes are divided by total energy consumption and thereafter deflated by PPI.
wage	Real wage (€ in fixed 2000 prices). Total compensation of employees is divided by the total number of employees and thereafter deflated by PPI.

Yet, with the available data, panel regression techniques were indeed feasible. When the data set contains not only cross-sections[4] but also repeated observations over time for each cross-section, panel regression techniques may provide better estimates compared to disjointed OLS regression of each individual cross-section. This is because panel regression takes into account also the variance across sections (and time) in making the estimates. However, panel regression is appropriate only if it makes sense to pool observations to search for some joint coefficient estimates while still allowing for certain differences between individual sectors and/or time periods. In our case, we have a panel data structure, where the cross sections (i.e. groups) are the respective industry sectors for which data were collected, and the time series are the annual observations between 1990 and 2003 for each industry sector.

Since all the chosen industry sectors are characterized as energy intensive or medium energy intensive, and all of them reside in countries that count as advanced North European economies (with the exception of Slovenia), it is assumed that the data set is sufficiently homogeneous to pool the observations. In Table 3, average unit energy costs are shown for each cross-section to provide an idea about the homogeneity across sections with respect to one of the most central variables in the analysis.

[3] The producer price index (PPI) for each sector is used as a substitute for the sector-specific GDP-deflator (the price level of all input factors) for which data were not available.
[4] Cross-sections refer to observations across different individuals, sectors, or countries at some point in time.

Table 3.3 Unit energy costs by industrial (NACE) sector and country. Average energy costs(€) per 100 € value added

	Denmark	Finland	Germany	NL	Slovenia	Sweden	UK
15.1	5.0	4.9	6.9	4.9	8.6	3.9	5.8
21.2	3.2	4.2	5.8	4.5	15.0	4.7	6.8
24.1	10.6	37.3	25.3	20.7	24.0	17.5	28.6
24.4	2.3	3.5	2.7	4.2	3.5	1.6	2.5
26.1	7.0	14.4	15.7	13.6	23.4	13.0	8.2
26.5	30.0	37.0	42.0	9.5	64.5	38.6	25.0
27.1-3	11.4	47.1	32.5	24.0	72.0	28.7	47.7
27.4	4.5	28.6	26.0	33.6	188.6	27.5	19.1

Test were carried out to determine the appropriate extent of pooling and on the basis of these test it was decided to use panel regression methods that allow the individual effects to differ across sectors, but not over time.[5]

The panel regression analyses centres around two basic models:

$$y_{it} = \alpha_i' + \beta' x_{it}' + u_{it} \tag{1a}$$

$$y_{it} = \beta' x_{it}' + (\alpha + u_i + \varepsilon_{it}) \tag{1b}$$

The first model is the fixed effects panel regression model. In this model, the omitted sector specific structural variables are treated as fixed constants over time (α'_i). The second is the random effects model in which the individual effect is considered as a time invariant component in the error term, that is, a random disturbance (u_i) of the mean unobserved heterogeneity (α). Although both models incorporate individual effects stemming from omitted variables, the central difference is that the random effects model represents the individual effects by a random component in the error term and thus prohibits correlation between these individual effects and the regressor variables x'.

Because of the endogeneity problems that apply to the models under investigation (see above), there is most likely correlation between the residuals and regressors and hence it is not very likely that the individual effects stemming from omitted variables are uncorrelated with the independent variables. This suggests that we use the fixed effects model.[6] Hausman specification tests were carried out to verify that the fixed effects model is superior to the random effects model for the relations we want to estimate.

[5] We tested for the existence of individual group effects and time effects by analysing the variance using the *pstats* procedure in RATS. The method works by decomposing the variance into three different alternatives, one with a random component plus individual effects only, a second with a random component plus time effects only, and a third with random plus joint individual and time effects. F-tests from one-factor and two-factor analyses of the variance are calculated for the three alternatives. The test results showed that individual effects alone were highly significant, that time effects alone were not significant, and that joint effects were also significant. But the test results also showed that joining the effects adds very little to model perfection as compared with the individual effects model (which has the advantage of leaving many more degrees of freedom). Therefore, the individual effects model was selected as our general approach to pooling the data.
[6] See Hsiao (2003: 41ff) for a further discussion of the theoretical and methodological considerations in choosing between fixed and random effects models.

4 The relation between energy taxes, competitiveness and output

There are a variety of indicators for industrial competitiveness. Focusing on the impact of energy taxes, the most relevant measure of price competitiveness is *unit energy costs*, which is defined as total energy expenditure (including taxes) per unit of gross value added in market prices. While unit energy costs is a partial measure of the price competitiveness of an industry, it is also a measure of energy intensity. Hence, if unit energy costs decrease as a consequence of substitution of labour for energy, which then turns out to increase unit labour costs, the firm will, on balance, not necessarily become more price competitive, but it will surely be less energy intensive. However, if real unit energy costs decrease and other unit input costs remain stable, it is indeed an indication that price competitiveness improved. We therefore investigated the impact on two partial measures of price competitiveness: unit energy costs and labour unit costs (defined as total wages and compensation per unit of gross value added in market prices).[7]

The original single equations used for estimating unit energy costs respective are listed as equation (2) and (3) below: All variables in these and the coming equations refer to their logarithmic (ln) values to make the results interpretable in percentage elasticities. Equations 2 and 3 appear as fixed effect models, where a_i respectively D_i are the fixed effect constants for each individual sector, τ *(t)* is a general linear trend and μ_{it} (u_{it}) are the residuals. The right-hand side include a lag of the dependent variables. The remaining symbols represent estimates of the regressor coefficients that are assumed to be joint for all sectors. In the underlying work, this assumption was relaxed by carrying out individual tests at the sector level by the very same basic model, which in this more disaggregated setting allows coefficients to vary across industry sectors, or across countries. The sector-specific results will be reported in a later article.

Through Hausman specification tests[8] it was investigated whether random effects models were more appropriate for estimating the unit cost equations and in both cases the answer was negative, as we suspected already from the endogeneity problem.

[7] It would be relevant to investigate the impact on total unit input costs (including costs of capital and raw materials) also, but since the data set does not contain sufficient information on these costs, it was not feasible to use it as an independent variable in a separate estimation.
[8] In order to harmonize the number of coefficients and covariance matrix from the two competing models, and thus simplify the calculations involved in the Hausman test, a general constant was added to the fixed effects model. The constant creates no disturbance as it washes out in the performed regression.

$$\text{uec}_{it} = \alpha_i + \beta * \text{epex}_{it} + \chi * \text{etax}_{it} + \nu * \text{ulc}_{it} + o * \text{urc}_{it} + \delta * \text{gva}_{it} + \tau * \text{trend} + \phi * \text{uec}_{i,t-1} + \mu_{it} \quad (2)$$

$$\text{ulc}_{it} = D_i + w * \text{wage}_{it} + e * \text{uec}_{it} + r * \text{urc}_{it} + y * \text{gva}_{it} + t * \text{trend} + f * \text{ulc}_{i,t-1} + u_{it} \quad (3)$$

The assumption behind the basic models is that unit energy and unit labour costs are, of course, determined first and foremost by the real price of respectively energy and labour. Moreover, they are determined by the unit costs of other input factors. For example, increasing unit labour costs will probably encourage industrial firms to use more energy as a substitute and thus raise unit energy costs. Unit costs are also influenced by the output quantity (gva) as economies of scale reduce average production costs and since growth tend to reduce problems with overcapacity.

Our proxy measure for unit raw material costs (cf. Table 3.2) is subject to more uncertainties than our similar measure for unit energy and labour costs. Moreover, it is not entirely clear that increasing raw material costs would lead to factor substitution towards energy as the consumption of the two often go together. We therefore tested the possibility for excluding urc as a regressor from both the uec- and ulc-equation and found that it could be excluded from the former, but not the latter.[9] Subsequently, we estimated the uec-equation without the urc-variable.

Table 4.1 and 4.2 shows the single equation estimation of respectively (2) and (3) without the urc-regressor in equation (2). The 56 dummy coefficients accounting for the fixed effects are not reported in the tables. The model statistics show a very good fit for both the uec- and the ulc-equation (r^2=0.989 respectively 0.968) The equations were estimated with *robusterrors* option in the RATS software package in order to correct the covariance matrix to allow for complex residual behaviour including heteroscedaticity and serial correlation. The estimated models were also tested for heteroscedaticity by means of the White test (1980) and for serial correlation by the Breusch-Godfrey test and the tests could not confirm the null hypothesis of respectively homescedaticity and no autocorrelation among the lagged residuals. When estimating the models without the lagged dependent variables, White and Durbin–Watson tests indicated similar problems.

[9] The test was carried out with the *exclud*e command in RATS which provide F, or in this case Chi-square (because robust errors were used), for the restriction that the listed coefficients are zero.

Table 4.1 Unit energy costs

Variable	Parameter estimate	Standard error	T-stat	p-value
epex	β = 0.527	0.0678	7.78	0.000
etax	χ = 0.030	0.0071	4.27	0.000
uwc	v = 0.293	0.0581	5.05	0.000
urc	*excluded*			
gva	δ = −0.511	0.0483	−10.57	0.000
trend	τ = 0.005	0.0021	2.62	0.008
uec(t–1)	f = 0.241	0.0457	5.29	0.000

Equation 2 estimated with fixed effects and robust errors

Table 4.2 Unit labour costs

Variable	Coefficient estimate	Standard error	T-stat	p-value
wage	w = 0.343	0.0360	9.55	0.000
uec	e = 0.123	0.0259	4.73	0.000
urc	r = 0.145	0.0277	5.25	0.000
gva	y = −0.325	0.0385	−8.45	0.000
trend	t = –0.004	0.0019	–2.41	0.016
ulc(t–1)	Φ = 0.330	0.0393	8.41	0.000

Equation 3 estimated with fixed effects and robust errors

The problems may relate to the many dummy variables included, but it could also be due to the endogeneity of the gva-, uec-, and ulc-variables which, in any case, suggests that it is preferable to estimate the uec- and ulc-equations simultaneously along with an output-equation, that is, as a 3-equation system. Before we move on to this next step, and before we start to interpret the results, we will shortly discuss and provide a first single equation estimate of output(gva).

The central measure of economic performance is growth in terms of output. Gross value added is the normal indicator of economic growth, and we therefore investigated the impact of energy prices, energy taxes, labour costs and raw materials costs on value added. According to economic theory, industrial supply is influenced by input factor prices. If the cost of production factors go up the cost of supplying the same quantity will increase and hence supply will be reduced causing *ceteris paribus* a decline in output. It is the total marginal costs of input factors that determines supply and hence it should not matter whether higher costs are caused by higher energy costs, labour costs or raw materials costs. Furthermore, if an increase in one of these costs is fully offset by decline in one or more of the other cost factors, supply should not be affected.

Output is also influenced by demand, that is, the consumer's willingness to pay for the products. Ideally, output should therefore be estimated by the means of a simultaneous supply and demand equation. However, in our case, we do not have sufficient information to estimate demand. Yet, the output measure is, to a certain extent, corrected for the demand factor as it is deflated by the producer price index (PPI). For our purposes, it should therefore be sufficient to estimate a supply-focused output-equation:

$$\mathrm{gva}_{it} = \kappa_i + \gamma * (\mathrm{uec}_{it} + \mathrm{ulc}_{it} + \mathrm{urc}_{it}) + \varsigma * \mathrm{trend} + \psi * \mathrm{gva}_{i,t-1} + \varepsilon_{it} \qquad (4)$$

In the output equation, unit input costs are represented by uec+ulc+urc, which should cover the full input costs since unit raw materials costs (urc) are measured here as all intermediary costs of production excluding energy costs and compensation of employees.[10]

Table 4.3 Gross value added

Variable	Coefficient	Standard error	T-stat	p-value
unit input costs	$\gamma = -0.490$	0.0380	–12.89	0.000
trend	$\zeta = 0.013$	0.0017	7.98	0.000
gva(t–1)	$\psi = 0.544$	0.0438	12.42	0.000

Equation 4 estimated with fixed effects and robust errors

Model 4 has a very high r^2 (=0.996), and the coefficients all have the expected sign just like the coefficients in model (2) and (3), but again there are problems with endogeneity, heteroscedaticity and autocorrelation. In the next step we therefore specified the full system of simultaneous equations – especially with a view to get a clearer picture of the reciprocal influence between output, unit energy costs and unit labour costs.

From the observation that the trend variable is more important in the output equation than in the uec- and ulc-equation (cf. the higher T-stat for trend in Table 4.3 vs. Table 4.1 and 4.2), we made further investigations and came to the conclusion that the output-model in the full equation system could be improved by working with sector-specific trends instead of a common trend. We therefore added a fixed effects dummy trend variable, but only to the output-equation within the system.[11]

$$\mathrm{gva}_{it} = \kappa_i + \gamma * (\mathrm{uec}_{it} + \mathrm{ulc}_{it} + \mathrm{urc}_{it}) + \varsigma_i * \mathrm{trend} + \psi * \mathrm{gva}_{i,t-1} + \varepsilon_{it} \qquad (5a)$$

$$\mathrm{uec}_{it} = \alpha_i + \beta * \mathrm{epex}_{it} + \chi * \mathrm{etax}_{it} + \nu * \mathrm{ulc}_{it} + \delta * \mathrm{gva}_{it} + \imath * \mathrm{trend} \qquad (5b)$$
$$+ \phi * \mathrm{uec}_{i,t-1} + \mu_{it}$$

$$\mathrm{ulc}_{it} = D_i + w * \mathrm{wage}_{it} + e * \mathrm{uec}_{it} + r * \mathrm{urc}_{it} + y * \mathrm{gva}_{it} + t * \mathrm{trend} \qquad (5c)$$
$$+ f * \mathrm{ulc}_{i,t-1} + u_{it}$$

Equations 5a to 5b were estimated with the *nlsystem* procedure in RATS which allow us to work with complex simultaneous equations, including formula, and use a generalized method of moments (GMM) estimator. GMM estimators apply an optimal weighting matrix to the orthogonality conditions that are used for correcting the covariance matrix (Hansen, 1982). The applied GM estimator corrects, as much as possible without changing the model, for problems with heteroscedaticity and serial correlation. Moreover, simultaneous estimation allow us to work with endogeneous variables (in this case, gva, uec and ulc) vis-á-vis instrumental variables (the regressors that appear only on the right-hand side) and

[10] It therefore includes intermediary costs related to administration also

[11] It might have been relevant to work with sectors-specific trends also for the uec- and ulc-equation, but that would require the estimation of another 112 parameters and thus deplete our degrees of freedom to an unacceptable extent. The dummy trend vector was therefore used where it mattered most – in the output-equation.

thus with a theoretically more adequate model. In such a model, the problems with residual variance and residual correlation are expected to be smaller.

The cost of simultaneous equations is the loss in degrees of freedom when so many parameters have to be estimated at once. Out of the 783 observations 435 were usable (the rest were skipped due to missing data in some variable). In total, 238 parameters had to be estimated including 224 dummy variables!. That still leaves enough degrees of freedom to be confident about the estimates. R^2 for the respective equations within the system are, as expected, very similar to those of the single equations. Yet, most of the coefficient estimates are quite different as we see from Table 4.4.

Table 4.4 Simultaneous estimation of gva, uec and ulc

Equation	Variable	Coefficient	Std. error	T-stat	p-value
GVA	unit input costs	γ = –0.241	0.0123	19.66	0.000
GVA	gva(t–1)	ψ = 0.200	0.0283	7.08	0.000
UEC	epex	β = 0.546	0.0494	11.04	0.000
UEC	etax	χ = 0.021	0.0079	2.66	0.008
UEC	uwc	v = 0.066	0.0699	0.95	0.344
UEC	gva	δ = −0.534	0.0585	−9.11	0.000
UEC	trend	τ = 0.009	0.0023	3.74	0.008
UEC	uec(t–1)	Φ = 0.289	0.0317	9.12	0.000
ULC	wage	w = 0.372	0.0365	9.55	0.000
ULC	uec	e = 0.050	0.0313	1.60	0.109
ULC	urc	r = 0.164	0.0246	6.67	0.000
ULC	gva	y = −0.265	0.0401	−6.61	0.000
ULC	trend	t = –0.006	0.0017	–3.54	0.016
ULC	ulc(t–1)	f = 0.362	0.0314	11.51	0.000

Equations 5a-5c subject to nonlinear GMM estimation

5 Interpretation of results

With the final estimation of the major dependent variables from equation 5a-5c, we can go on to interpret the results.

5.1 Unit energy costs

The results show, as expected, that rising energy prices over time lead to increasing unit energy costs, although the impact is not a 1 to 1 relation. From the estimation of the simultaneous equation (5b), it appears that the long-term impact –after factor substitution, output adjustment, etc. – of a 1 per cent increase in the real energy price is a 0.77 per cent increase in unit energy costs.[12] This is very close to the estimate in the single uec-equation (cf. Table 4.1).

More interesting, the effect on unit energy costs of 1 a per cent energy tax increase is 26 times as little (0.546/0.021) compared to a 1 per cent increase in the market energy price. Since the level of market energy prices is, on average, 17 times higher than energy taxes for the observations in this data set, the result indicates that a change in the energy tax has a relatively lower effect on unit energy costs than the same absolute change in the market energy price. Hence, there is some indication that energy taxes do not harm competitiveness as much as ordinary price increases.[13] The total long-term effect of a 1 per cent energy tax increase is that unit energy costs go up by some 0.03 per cent.

Unit labour costs (ulc) tend to have a weak positive impact on unit energy costs, which is what we would expect from factor substitution. Yet, the estimate is only significant in the single equation. The results moreover show that higher output reduce unit energy costs, which is also expected, although it is a bit unexpected that the relation is almost as strong as the energy price effect. This might indicate that the real recursive relation between gva and uec is not fully captured even in the simultaneous equation system.

5.2 Unit labour costs

The results show the same basic pattern as above. Unit labour costs are first of all determined by the price of labour, that is, real wages. But the wage–ulc relation is more inelastic than the epex–uec relation. Unit energy costs and unit raw materials costs both have a positive influence on unit labour costs as the firms substitute towards labour – especially when the price of raw materials go up. And again, output work through economies of scale to reduce unit labour costs.

[12]This is because 0.546/(1-0.289) = 0.77 after taking into account the correction for lagged dependent variable (cf. Greene, 2000: 727).
[13] In the single equation, the result is different. Here energy taxes tend to have the same effect as market energy prices when the same absolute size is compared. Yet the simultaneous estimation is probably more credible as it takes into account the recursive impact from energy taxes via output.

5.3 Economic output

The output equation clearly illustrates the need for simultaneous estimation. The single equation estimate indicate an extremely steep supply curve since a 1 per cent increase in unit input costs lead to a 1.07 per cent decline in output (after correcting for the lagged endogeneous variable). The estimate from the simultaneous equation 5a is theoretically more justified and also much more realistic. According to this estimate, a 1 per cent increase in unit input costs leads to a 0.3 per cent decline in output.

5.4 The effects of energy taxes on economic performance

On that basis, we conclude the following with respect to the average impact of energy taxes on competitiveness and output. Competitiveness is reduced as a consequence of higher energy prices as it leads to both higher unit energy costs and unit labour costs. However, unit energy costs only go up by 0.3 per cent and unit labour costs by 0.023 per cent if energy taxes increase by as much as 10 per cent. If, for example, energy costs amount to 10 per cent and labour costs amount to 50 per cent of all input costs, the final effect of a 10 per cent energy tax increase will be a small 0.04 per cent decline in output. Hence competitiveness and economic output is not affected very much by changes in energy taxes. This conclusion applies to changes within the scope of experienced fluctuations in the period under investigation. Moreover it does not distinguish between the tax level at which the tax increase occurs. A many-doubling of energy taxes may thus have more drastic (exponential) effects, especially if it is a many-doubling of an already high tax level.

5.5 Searching for the Porter effects

In the theoretical section, we identified two possible Porter effects, a supply-oriented that mainly operates via factor substitution and energy efficiency improvements and a demand-oriented mainly operating via green innovation that raise demand for industry products. In other words, the first Porter effect mainly works by reducing energy consumption and the second mainly works by increasing the consumers' willingness to pay. The influence of market energy prices and taxes on energy consumption can be roughly approximated by the following single equation:

$$\begin{aligned} \text{encon}_{it} &= D_i + a*\text{epex}_{it} + b*\text{etax}_{it} + c*\text{wage}_{it} + d*\text{gva}_{it} + g*\text{trend} \\ &+ h*\text{e}ncon_{i,t-1} + u_{it} \end{aligned} \quad (6)$$

A more correct estimate of energy consumption would be expected from simultaneous factor input equations, but since we have no reliable data on the price of raw materials and capital, we satisfy for the proxy type in equation (6) which normally works reasonably well in estimating energy consumption.

Table 5.1 Energy consumption

Variable	Coefficient estimate	Standard error	T-stat	p-value
epex	$a = -0.435$	0.0641	–6.78	0.000
etax	$b = 0.011$	0.0081	1.35	0.178
wage	$c = -0.093$	0.0723	–1.29	0.198
yvol	d = 0.335	0.0443	7.56	0.000
trend	$h = 0.004$	0.0029	1.62	0.105

Equation 6 estimated with fixed effects and robust errors

The results show that the long-term elasticity of energy consumption with respect to market energy prices is –0.435 which is well in accordance with recent findings in the area of industrial energy price elasticities.[14] Industrial output quantity has the expected positive impact on energy consumption although it is far from constant returns to scale. The other relations are not significant. Surprisingly energy taxes do not have a significant negative influence on energy consumption. This could be due to imperfect model specification (the lack of individual factor equations). Yet, it could also be the case, that energy taxes mainly work through the demand-related Porter effect on output and therefore implies a positive recursive influence on energy consumption via output.

To test further the idea that energy taxes has a positive direct impact on demand we re-estimated the simultaneous equation system 5a-c by adding the etax variable to the right-hand side of equation 5a. Although this implies some multicollinearity, the problem should be very small as the energy tax is only a tiny part of total input costs. The results are shown in Table 5.2.

Table 5.2 Simultaneous estimation of gva, uec and ulc

Equation	Variable	Coefficient	Std. error	T-stat	p-value
GVA	etax	$\pi = 0.023$	0.0055	4.24	0.000
GVA	unit input costs	$\gamma = -0.241$	0.0120	–20.05	0.000
GVA	gva(t–1)	$\psi = 0.206$	0.0277	7.44	0.000

Re-estimation of 5a-5c by adding etax with coefficient named π to 5a

We find that energy taxes have a very significant direct impact on output in that a 10 per cent increase in energy taxes lead, on average, to an increase in gva by some 0.23 per cent. The two other coefficients and their statistics remain relative stable after the inclusion of etax. in 5a. Although the additional results in Table 5.1 and 5.2 far from answer all open questions related to the hidden Porter effect[15], we have at least provided a strong indication that there is indeed a Porter effect that mitigates the immediate negative impact of green energy taxes on economic perform-

[14] We choose to exclude the lagged dependent variable this time as it tend to overdetermine the regression. The main conclusions are not affected by whether it is included or not, although the long-term coefficients tend to moderate. Yet, heteroscedaticity and autocorrelation problems apply (the Durbin-Watson statistic is only 1.09). A truly dynamic cointegration model would probably be required to do away with this and perhaps be able to give a better account of the tax effect.

[15] A direct regression of willingness-to-pay (demand) against energy taxes and other demand-related variables would have been preferable, but is not feasible with the available WP3 data set.

ance. We also reach the tentative conclusion that the operating Porter effect works through demand-related green innovation rather than supply-related factor substitution.

6 Conclusion

In the beginning of the article we posed the question whether Porter effects, which are normally associated with environmental regulation of a more traditional kind, also play a role with respect to economic instruments of environmental regulation such as (green) energy taxes. In general, the literature has experienced difficulties in providing clear-cut evidence in favour of the Porter hypothesis. Yet economic instruments of environmental regulation have quantitative properties that provide for better access to test for effects on competitiveness on economic performance. In this article such an attempt was made with respect to energy taxes. Energy taxes were described and carefully measured along with a number of other central economic variables in the WP3 data set containing time series of eight relatively energy-intensive industry sectors in seven different countries.

By the means of econometric panel regression techniques we have demonstrated the impact of market energy prices, energy taxes, labour and raw materials costs on price competitiveness and economic output. We have quantified the economic impact of energy taxes and have shown that higher energy taxes lead to a moderate increase in unit energy costs and a small increase total unit input costs which again lead to an even smaller reduction in economic output according to our simultaneous equation model. We have also demonstrated that, with a high probability, the very moderate negative economic impact is the result of Porter effects – in particular because the application of (mainly green) energy taxes stimulate efforts within the industries that in turn raise the demand for their products and thus have a direct positive impact on output that counteracts the negative supply effects of the tax increase. We also provided strong indications that energy taxes have different effects on competitiveness and output than market energy prices of similar size.

With the available data, it is, however difficult to say whether the interesting effects can be ascribed solely to the energy taxes, or if they energy taxes systematically go hand in hand with various kinds of government support (for example earmarked subsidies for energy-savings, public information and marketing campaigns and compensation of the industries with respect to other taxes or social contributions). A more rigorous testing would require some measure of government support to be included in the models. It would also require a better demand model than the proxy we have devised under the present conditions, along with more reliable data on capital and the price of raw materials. Moreover, it would require much longer time series that allow for dynamic VAR estimation methods and hence a more reliable account of the complex endogeneity among the central variables.

This article, which centres around the aggregate/average effects across all industry sectors, will be followed up by an article that applies the models on a disaggregated basis to the respective industry sectors and countries within the data set. It has the purpose of analyzing similarities and differences between the cross-sections and further test the validity of the models.

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An assessment of the impacts of environmental tax reforms on the competitiveness of selected industrial sectors

WP3

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1. Introduction

The objective of this report is to assess whether the energy-related environmental tax reforms (ETRs) [1] that were implemented in seven European Union countries between 1990 and 2001 have had any impact on the competitiveness of selected industrial sectors in those countries[2].

Eight sectors have been selected for the analysis, spanning a range of energy and trade intensities. Six of these were "pre-selected" in the Technical Annex; with the remaining two being chosen on the basis of the screening exercise undertaken in Work-package 2[3]. The sectors are:

- Food and food products (NACE 15.1, 'MMP')
- Paper and paper products (NACE 21.2, 'PPP')
- Basic chemicals (NACE 24.1, 'BCH')
- Pharmaceuticals (NACE 24.4., 'PHM')
- Glass and glass products (NACE 26.1, 'GLA')
- Cement, lime and plaster (NACE 26.5, 'CLP')
- Ferrous metals (NACE 27.1-3, 'FM')
- Non-ferrous metals (NACE 27.4, 'NFM')

This report is one of four emanating from the analyses of these eight sectors undertaken in Work-package 3. The other three reports provide:

- an assessment of the Porter hypothesis in relation to energy efficiency;
- an econometric evaluation of the impact of carbon energy taxes / prices on energy use for each sector for the period 1990-2002;
- an assessment of the potential for cost-efficient improvements in energy efficiency for each sector.

Underlying the analyses is a series of country-datasets (deliverables DL3.2 and DL3.3); with each dataset containing generic data such as exchange rates and emission factors, and sector-specific data on energy use, energy prices and taxes, economic variables and labour market variables. Wherever possible these datasets have been collated from official sources (i.e. national statistical agencies, Eurostat, IEA, etc.). However, in some cases it has been necessary to adjust data, or to estimate missing data. The data collection exercise is covered in a separate report which provides information on the data sources that have been used for each country, together with details of any adjustments that have been made and the assumptions that underpin any estimated data.

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[1] That is where taxes were introduced, or increased, on energy products or carbon emissions; with the revenues being used explicitly to reduce employer or employee labour taxes.

[2] The countries are Denmark (DK), Finland (FI), Germany (DE), the Netherlands (NL), Slovenia (SI), Sweden (SE) and the United Kingdom (UK). Details of the tax changes that were introduced under the reforms in each country are provided in Speck (2005).

[3] In the Technical Annex, it was specified that the analysis would include ferrous metals (27.1-3), non-ferrous metals (27.4), non-metallic mineral products (26), paper and pulp (21) – all at the request of the Commission, and basic chemicals (24.1). For the two sectors defined at the 2-digit level, specific 3-digit sub-sectors were selected on the basis of data availability in the case-study countries.

By definition, if an ETR raises the production cost of a firm[4], or the average production cost for a sector, then it has a negative impact on competitiveness compared to the (hypothetical) situation if the ETR had not been implemented – all else being equal. However, from a policy perspective it is more relevant to consider whether there has been any deterioration in competitiveness compared to the (actual) situation before the ETR was implemented. This will depend on the magnitude of the "ETR impact" relative to the impacts of other factors that affect competitiveness. For example, if the prices of raw materials or components are falling, or if production efficiency is improving, then unit production costs may fall despite the negative impact of the ETR. Even if the ETR does cause unit production costs to increase, there may be an improvement in competitiveness if the costs of producers in other countries are rising more quickly (for whatever reason). Conversely, there may be a deterioration in the competitiveness of a sector even if the ETR impact is positive.

In recognition of this, the overall objective for the report is broken down into two parts, which are encapsulated in the following two research questions:

- How significant were the ETRs in terms of their impacts on unit production costs?
- Is there any evidence that the selected sectors have suffered a decline in competitiveness (or enjoyed an improvement) during the period 1990-2002?

Only if a sector has suffered a decline in competitiveness <u>and</u> the ETR has had a large impact on its unit production cost, is it reasonable to conclude that the reform has had a significant negative effect. If only one of the two conditions holds, then this is an indication that other factors have had a significant effect – either to offset the negative impact of the ETR, or to cause the decline in competitiveness.

The first question is addressed in section 2 of the report, while the second is addressed in section 4. A number of indicator variables are used to assess the changes in competitiveness, and the theoretical justification for these is provided in section 3. The answers to the two questions are pulled together in Section 5 to provide some overall conclusions regarding the significance of the ETRs for competitiveness.

[4] If the ETR causes technological (or managerial) improvements in efficiency that would not otherwise have occurred, then the ETR may cause unit production costs to fall and hence competitiveness to improve. This extension of the "Porter Hypothesis" is investigated in one of the other reports from Work-Package 3.

2. ETRs and units costs

This opening section of the report provides an assessment of the impacts of the ETRs on the production costs of the eight selected sectors.[5] The main focus is on the negative impacts of the increases in carbon-energy taxes, which are determined by two factors: a) the magnitudes of the increases in the average energy tax rates faced by the sectors; b) the importance of energy costs to the sectors' total production costs. These factors are considered individually, before being brought together to provide a view of the overall impacts of the energy tax increases on unit production costs. The positive impacts of the ETRs are considered for the two countries (Germany and the United Kingdom) where the revenues were explicitly used to reduce employers social contributions; allowing the net impact of the reforms to be estimated for these two countries.

2.1 Imputed carbon energy tax rates

The imputed carbon-energy tax rate for a sector is defined as total carbon-energy tax payments divided by total energy expenditures excluding taxes. This includes all carbon energy taxes, not just those that relate specifically to the ETRs. For example, in the United Kingdom the imputed tax rates include the hydrocarbon duties on fuel / gas oil and the fossil fuel levy on electricity, while only the Climate Change Levy is formally part of an ETR.

Time series for the tax rates over the period 1990-2002 are shown in Figure 2.8 at the end of this section. The average tax rate is around five percent for most countries and sectors. Exceptions occur in the cement sector (26.5) for Finland and in the ferrous metals sector (27.1-3) for Finland, Sweden and the Netherlands, where the average rates are closer to 20 percent. There are large differences across sectors and within sectors across countries; with overall rates ranging from around 1% to over 40%. This variation in the level of tax rates is due to a number of reasons.

- Differences in actual tax rates between fuel types, combined with differences in fuel mixes between sectors.
- Differences in actual tax rates (Euros/GJ) and sector exemptions between countries.
- Differences in energy prices between sectors and countries, so that even if firms were all subject to the same actual tax rate per joule, the imputed tax rate will differ.

Turning to the trends in the data, an increase in rates can be observed in most countries/sectors from the mid-1990s onwards with the strongest trends occurring in Denmark, Finland and the Netherlands. Notable exceptions occur in the first half of the study period in Sweden, Germany and the United Kingdom.

- Sweden introduced relatively high tax rates on emissions of CO_2, SO_2 and NO_X in the early 1990s.[6] However from 1993 onward the manufacturing industry was exempted from all carbon energy taxes, leading to a dramatic drop in its tax burden and hence the imputed tax rate.[7] Over the remainder of the study period tax rates follow the slight upward trend observed in the other countries.

[5] For a more detailed discussion of the ETR in the selected countries see Speck (2006).
[6] Industry in the cement sector (26.5) was exempt from these high rates.
[7] They did continue to pay a fraction of the CO_2 tax. See Speck (2006) for details.

- The decrease in the tax rate from 1995-96 in Germany is due to the end of the 'Kohlepfennig', a levy on electricity used to subsidize the coal industry. From 1996 onward tax rates in Germany are also increasing.
- In the UK the fossil fuel levy on electricity came down steeply in the mid 1990s and was set to zero in 1998. Tax rates rise again in 2001 with the introduction of the climate change levy.

The impact of the ETR (Δ_TAX_{ETR}) in each country is defined as the difference between the imputed tax rate in the year preceding the ETR and the tax rate after the ETR. Depending on the timing of the ETR this figure may not be equal the change in carbon energy taxes over the study period (Δ_TAX) which is calculated as the difference in the tax in 2002 and the tax in 1990 (or the first year when data is available for a given country). The difference is particularly noticeable for the United Kingdom, where the imputed tax rate in 2002 is lower than in 1990 for some sectors and hence Δ_TAX is actually negative.

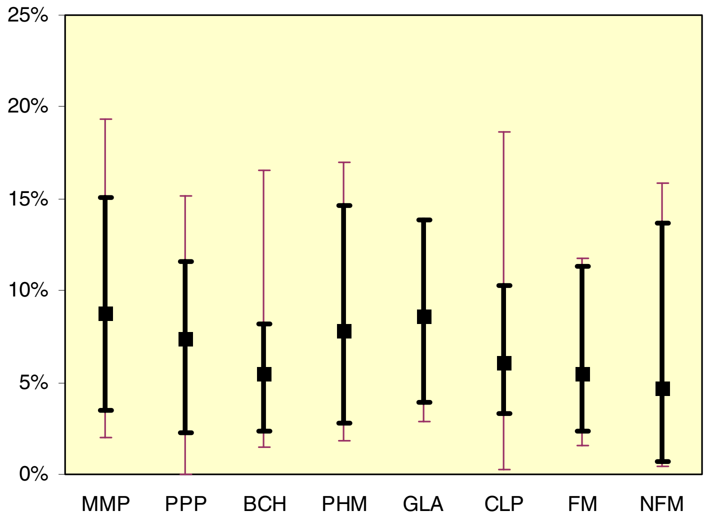


Figure 2.1 Impact of ETRs on imputed carbon-energy tax rates (Δ_TAX_{ETR})

Figure 2.1 shows the range of values for Δ_TAX_{ETR} for each of the eight sectors (the light maroon lines). The heavy black lines represent the ranges when the highest and lowest values are excluded, together with the resultant average values across the seven countries. The average values range from 5% to 8%; with the highest average impacts being seen for the meat products, pharmaceuticals and non-ferrous metals sectors. The lowest average impacts for the ETRs are seen for the basic chemicals and the two metals sectors, reflecting the many exemptions granted to these sectors.

2.2 Energy share of unit production costs

The impact of change to the imputed tax rate for each sector depends on the importance of energy costs in its overall cost-base. Figure 2.9 (at the end of this section) show the time-series for the energy share of total costs for each sector / country; where total costs are defined as total intermediate costs plus labour costs (including taxes). In most sectors / countries energy expenditure shares are either falling, or fairly stable; although there are some notable exceptions. However, these temporal variations are generally not that great and may reflect data quality issues rather than genuine trends. As with the imputed tax rates, there are significant differences between sectors and, within sectors, between countries. This can be seen in Figure 2.2, (where the heavy black lines again show the ranges with the outliers excluded), where the share of total costs attributable to energy ranges from less than 1% to almost 30%.

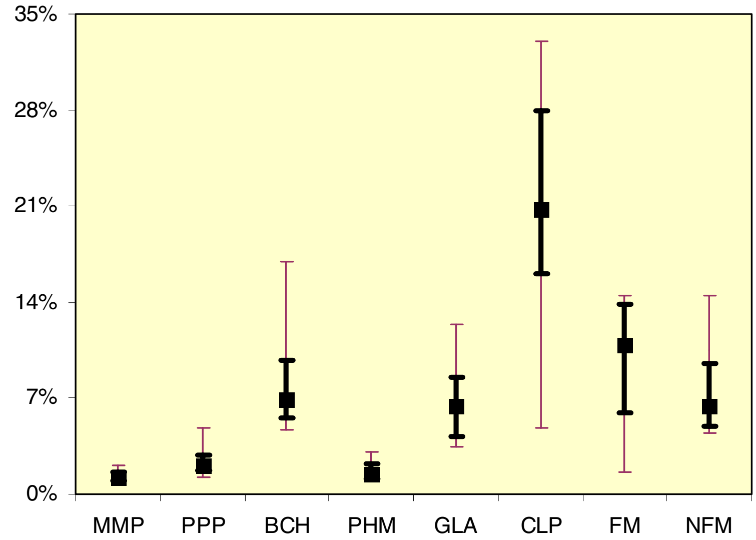


Figure 2.2 Energy expenditure as a percentage of total costs

The eight sectors fall into three broad groups, depending on the significance of their respective energy expenditures.

- For the meat processing sector (MMP), the paper products sector (PPP) and the pharmaceuticals sector (PHM), the share of total costs attributable to energy is only around 2%.
- For the basic chemicals sector (BCH), the glass sector (GLA) and the two metals sectors (FM and NFM) energy costs account for around 5%-10% of total costs[8].
- The cement industry (CLP) is by far the most energy intensive, with energy expenditure accounting for around 20% of total costs on average.

The relatively large ranges in the energy expenditure shares for some of the sectors shown in Figure 2.2 may be due to data quality issues and/or differences in energy prices and fuel mixes between countries. However, another potential reason for the differences is that the sectors studied, even at this level, are not homogeneous. Within a given sector the product mix and hence the energy levels required as inputs to the production process may vary considerably across countries.

2.3 Overall impact on production costs

The overall impacts of the energy tax increases on total production costs are derived by multiplying the changes in the imputed tax rates (Δ_TAX_{ETR}) by the respective energy shares of total costs. The resultant impacts are shown in Figure 2.3 (where the heavy black lines again show the ranges with the outliers excluded).

[8] Data for Slovenia for sector 27.4 was deemed unreliable and is not shown in the graph. Energy expenditures were five times higher than in the other countries.

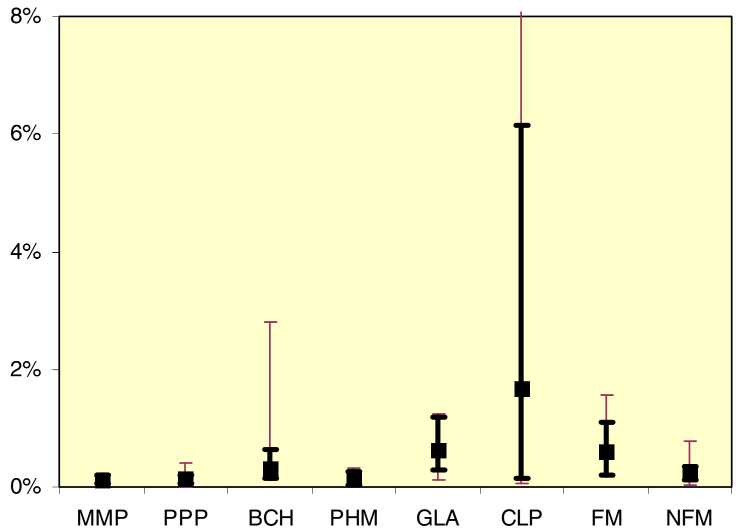


Figure 2.3 Impact of energy tax increases on total production costs

As one would expect – given the relatively uniform impact of the ETRs on imputed tax rates – the relative magnitudes of the impacts across sectors are determined largely by differences in the shares of total costs attributable to energy. Consequently, the sectors can be classified into the same three broad groups. For the three sectors with low energy shares (i.e. MMP, PPP and PHM), the impact on total costs is minimal; while for the four mid-range sectors (BCH, GLA, FM and NFM) the tax increases have raised production costs by less than 1%. Even for the cement sector (CLP), the average increase in production costs has only been 2%; although there was a 6% increase for Slovenia.[9]

These estimates do not take account of any reductions in production costs that might arise from the recycling of the revenues raised by the energy tax increase – in the form of other tax reductions. As such, they should be treated as upper bounds for the overall impacts. For most of the countries, the tax reductions are not explicitly identified and therefore it has not been possible to estimate these offsetting impacts. However, in the cases of Germany and the United Kingdom there were explicit reductions in employers' social contribution rates and hence it is possible to assess the positive impacts of the revenue recycling on production costs for these two countries.

[9] Some problems with the tax data for Slovenia were discovered after the analysis had been completed. As a result the magnitude of the tax increases and the impacts on total costs are both overstated. This will also have resulted in the average value being overstated slightly, but this is not significant.

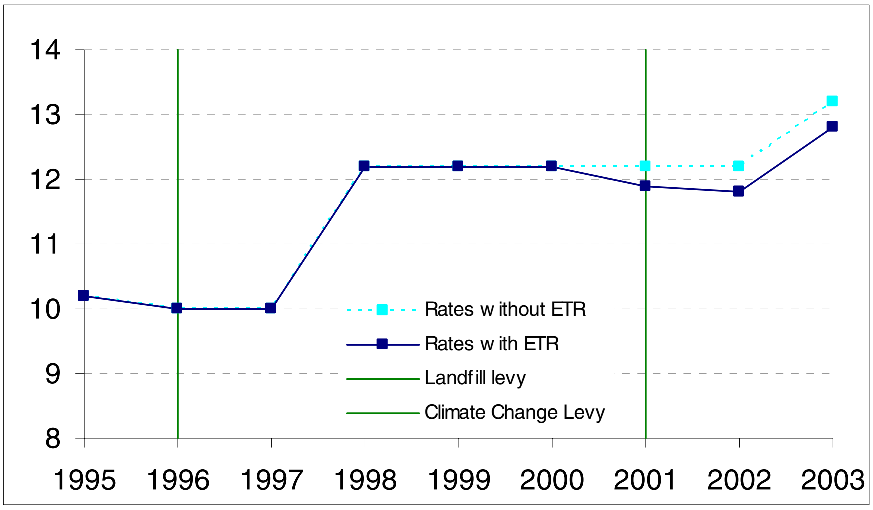


Figure2.4 Employers National Insurance Contribution Rates in the UK

Source: Annual Abstract of Statistics, UK 2006.

Figure 2.4 shows the trend in the employer national insurance contribution (NIC) rates in the United Kingdom.[10] The rate dropped slightly from 10.2 to 10% in 1996 due to revenue recycling measures introduced as part of the Landfill Levy, but was increased substantially two years later. In 2001, the rate was reduced by 0.3% points (from 12.2 to 11.9 %) when the Climate Change Levy (CCL) was introduced. Although the rate rose again in 2003, it is assumed that this increase would have occurred without the ETR and hence that the reduction due to the ETR is maintained in that year (i.e. the counterfactual rate is 0.3% points higher than the actual rate).

In Germany there was a 1.2% point reduction in the combined pension contribution rate for employers and employees between 1999 and 2002, with a slight increase in the following year (see Figure 2.5). However, it has been estimated that as a result of general demographic developments, increases in the contribution rate would have been required and that the rate would have risen to 21.2% by 2003 in the absence of the ETR. Consequently, the real reduction in the contribution rate rose from 0.6% points in 1999 to around 1.7% points by 2003. This decrease was split equally between employers and employees. Consequently, for the purposes of this analysis the reduction in the employers' contribution rate has been taken as half of the average decrease over the four year period – i.e. 0.6% points.

[10] The rate shown is the employers' standard (contracted out) contribution rate for the upper earnings limit.

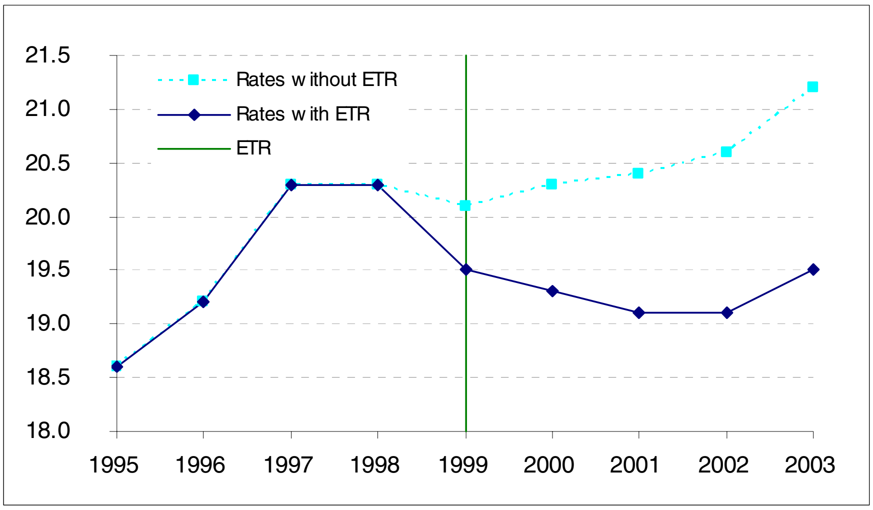


Figure 2.4 Employer and Employee Pension Contribution Rates in Germany

Source: German Pensions Statistics, 2006.

The changes in the imputed energy tax rates in the two countries are shown in Figure 2.8 at the end of this section. However, because the charts include all countries it is difficult to isolate the trends for Germany and the United Kingdom. Consequently, the time series for these two countries over the period 1995-2002 have been extracted for a token sector – the meat processing sector (15.1) – and are shown Figure 2.5. While there are some minor differences for the other sectors, the picture is essentially the same in all cases. In the United Kingdom, the imputed energy tax rate fell after 1996 following the reduction of the fossil fuel levy, before rising in 2001 from 1.5 to 4.3% with the introduction of the Climate Change Levy. In Germany the average tax rate fell in 1996 with the removal of the "Kohlepfennig" before rising in 1999 from 4.3 to 7.2% with the introduction of the ETR.

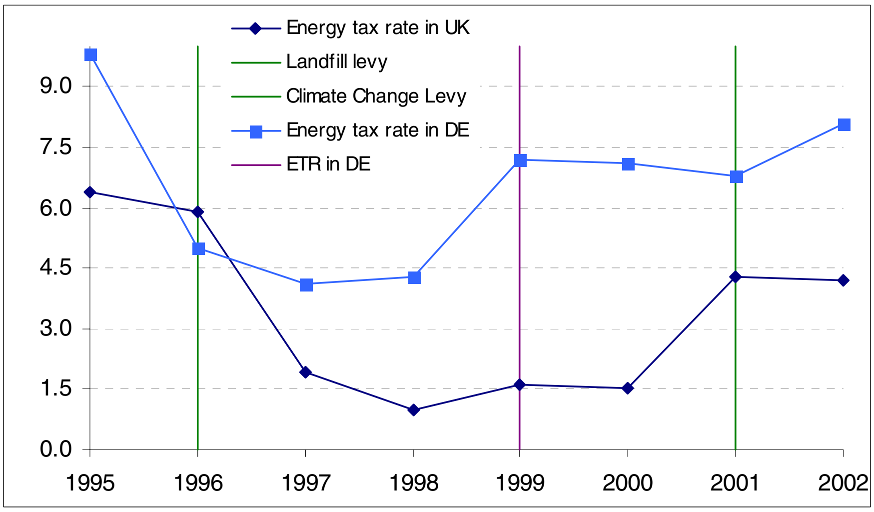


Figure 2.5 Imputed energy tax rates for sector 15.1 in the UK and Germany

In Table 2.3 the total impact on costs of the ETRs is calculated for the UK and Germany for each of the eight sectors. For each factor, the change in the average tax rate as a result of the ETR (Δ_TAX_{ETR}) is calculated as the difference between the tax rates in 2002 (post-ETR) and in 1998 (pre-ETR).[11] The impacts of the changes in factor taxation on the total production costs (shaded yellow in the table) are calculated by multiplying the change in the tax rates by the factors' respective shares of total cost. The total impact of the ETR on production costs (shaded green) is then equal to the sum of the two impacts.

In the United Kingdom, the increase in energy taxes ranges from 1.4% points for the basic chemicals sector (BCH) to 5% points for the cement sector (CLP); while the energy share of total cost ranges from 2% for the meat processing and pharmaceutical sectors (MMP and PHM) to 20% for the sector (CLP). In contrast, there is less variation in the labour share of total costs; with the share ranging from 19% for the non-ferrous metals sector (NFM) to 37% for the glass sector (GLA). The reduction in employer national insurance contribution rate in all eight sectors is assumed to be equal to the national average – i.e. 0.3% points[12].

In Germany the increase in energy taxes is slightly higher than in the United Kingdom. However, the relative scales of the increases across the sectors is very different; with the basic chemicals sector (BCH) suffering the largest increase, at 6.7% points, and the cement sector (CLP) the smallest, at 3.3% points. As with the United Kingdom, the reduction in the employers' pension contribution rate is assumed to be uniform across sectors – at 0.6% points. The energy and labour shares of total costs follow a similar pattern to the United Kingdom, with a couple of exceptions (e.g. the labour share for the meat processing sector is much lower in Germany).

[11] For the UK only the impact of the CCL is taken into account here.

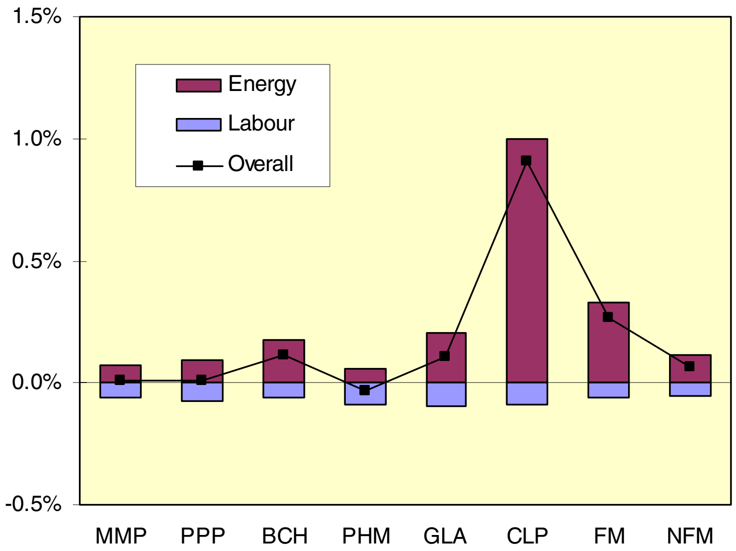
[12] Because of there is a minimum threshold below which the contribution rate is zero, the actual reduction will vary from sector to sector. However, this is more significant for service sectors and any variations are not likely to be significant for the eight COMETR sectors.

Table 2.3 Impact of ETR on total costs with and without revenue recycling (all figures are in %)

Sector		Energy			Labour			Total Impact
		Impact on tax	Share of TC	Impact on TC	Impact on tax	Share of TC	Impact on TC	
United Kingdom	MMP	3.5%	2.0%	0.07%	-0.3%	23.0%	-0.06%	0.01%
	PPP	2.2%	4.0%	0.09%	-0.3%	29.0%	-0.08%	0.01%
	BCH	1.4%	12.0%	0.17%	-0.3%	22.0%	-0.06%	0.11%
	PHM	2.8%	2.0%	0.06%	-0.3%	33.0%	-0.09%	-0.03%
	GLA	2.9%	7.0%	0.20%	-0.3%	37.0%	-0.10%	0.10%
	CLP	5.0%	20.0%	1.00%	-0.3%	32.0%	-0.09%	0.91%
	FM	1.9%	17.0%	0.33%	-0.3%	22.0%	-0.06%	0.27%
	NFM	1.5%	7.5%	0.11%	-0.3%	19.0%	-0.05%	0.06%
Germany	MMP	5.0%	1.5%	0.08%	-0.6%	14.0%	-0.08%	0.00%
	PPP	4.9%	3.0%	0.15%	-0.6%	26.0%	-0.14%	0.01%
	BCH	6.7%	8.0%	0.54%	-0.6%	23.0%	-0.13%	0.41%
	PHM	5.4%	1.5%	0.08%	-0.6%	29.0%	-0.16%	-0.08%
	GLA	3.9%	12.0%	0.47%	-0.6%	32.0%	-0.17%	0.30%
	CLP	3.3%	30.0%	0.99%	-0.6%	28.0%	-0.15%	0.83%
	FM	3.6%	13.0%	0.47%	-0.6%	23.0%	-0.13%	0.34%
	NFM	5.6%	8.0%	0.45%	-0.6%	18.0%	-0.11%	0.34%

The overall impacts of the ETRs are shown graphically in Figure 2.6, from which it can be seen that there is a great deal of similarity between the two countries. In each case, the ETR has had the greatest impact on the cement sector (CLP), with a net impact of around 0.8%-0.9%, reflecting the high share for energy costs in total production costs for this sector. In the meat processing, paper and pharmaceutical sectors (MMP, PPP, and PHM), the reductions in labour costs almost exactly offset the increases in energy costs. For the remaining four sectors (BCH, GLA, FM and NFM), the ETRs have led to small increases in total production costs; with net impacts in the range 0.1%-0.3% in the United Kingdom and in the range 0.3%-0.4% in Germany.

a) United Kingdom



b) Germany

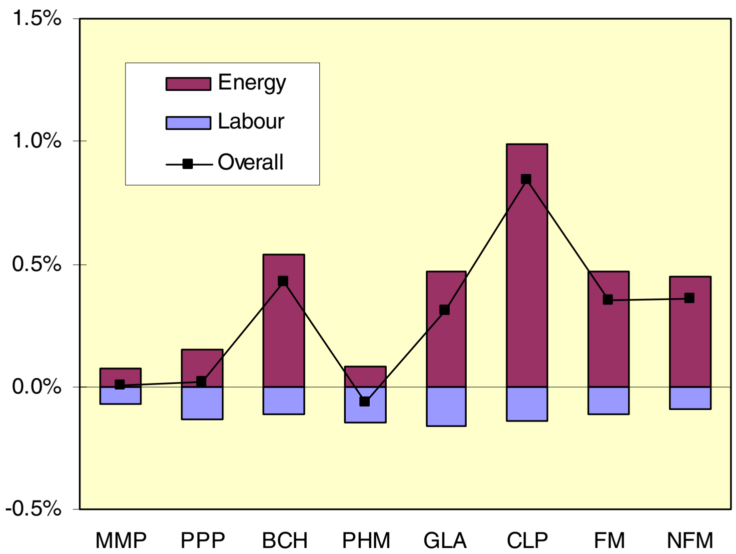


Figure 2.6 Net impacts of ETRs on production costs

2.4 Summary

In this section data on imputed energy tax rates and energy expenditures as a percentage of total costs has been presented and discussed for the selected sectors and countries over the study period. In addition, the ETRs in the UK and Germany have been considered in more detail and the combined effect of energy taxation and revenue recycling has been calculated for all sectors in these two countries.

The overall conclusion is that while the ETRs have increased the average level of energy taxation by around 5-10% points on average and up to 15-20% points in some cases, the relatively low share of costs attributable to energy has meant that the impact on total production costs has been minimal. Only for the cement sector is there any evidence that the ETRs may have had a significant impact, with an average increase in production costs of around 2%. Moreover, this is without taking account of any cost reductions that might have arisen from the recycling of the revenues raised by the energy tax increases. In the United Kingdom and Germany, the positive impacts arising from the reductions in employer social contribution rates were sufficiently large for the three sectors with the lowest energy intensity (meat processing, paper and pharmaceuticals) to completely offset the negative impacts of the energy tax increases.

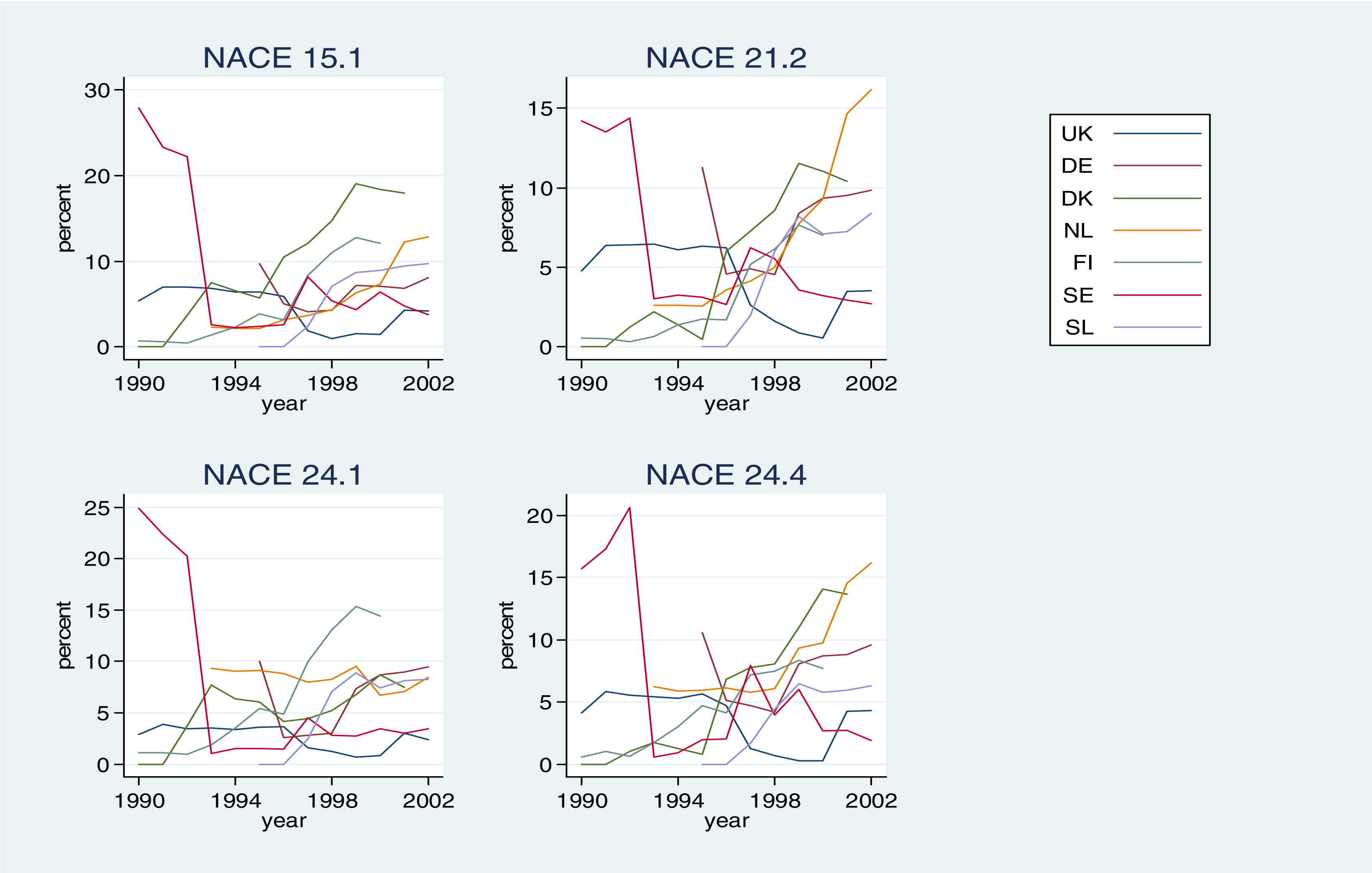


Figure 2.8(a) Imputed Carbon energy tax Rate by Country and Sector (15.1 – 24.4)

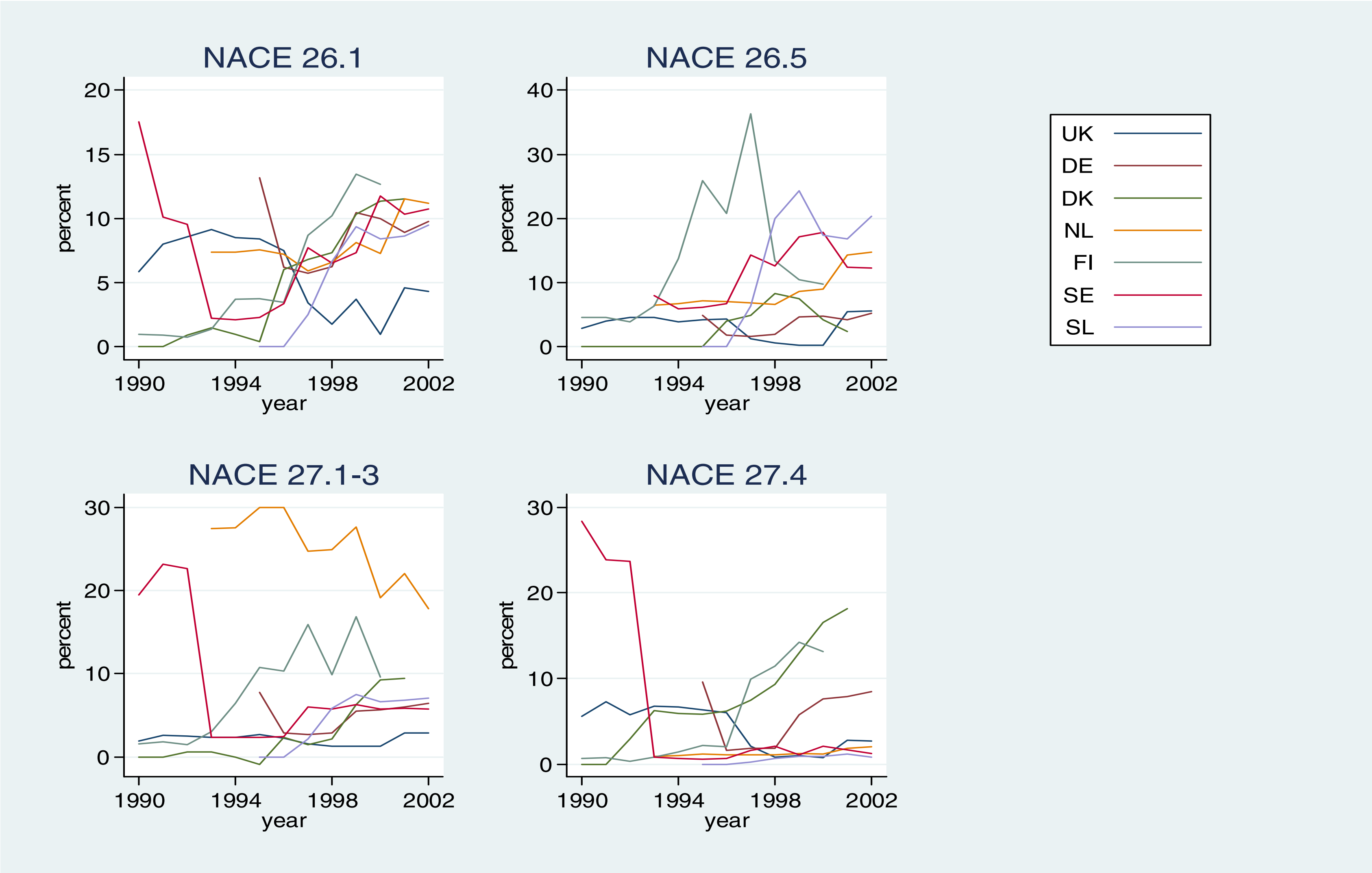


Figure 2.8(b) Imputed Carbon energy tax Rate by Country and Sector (26.1 – 27.4)

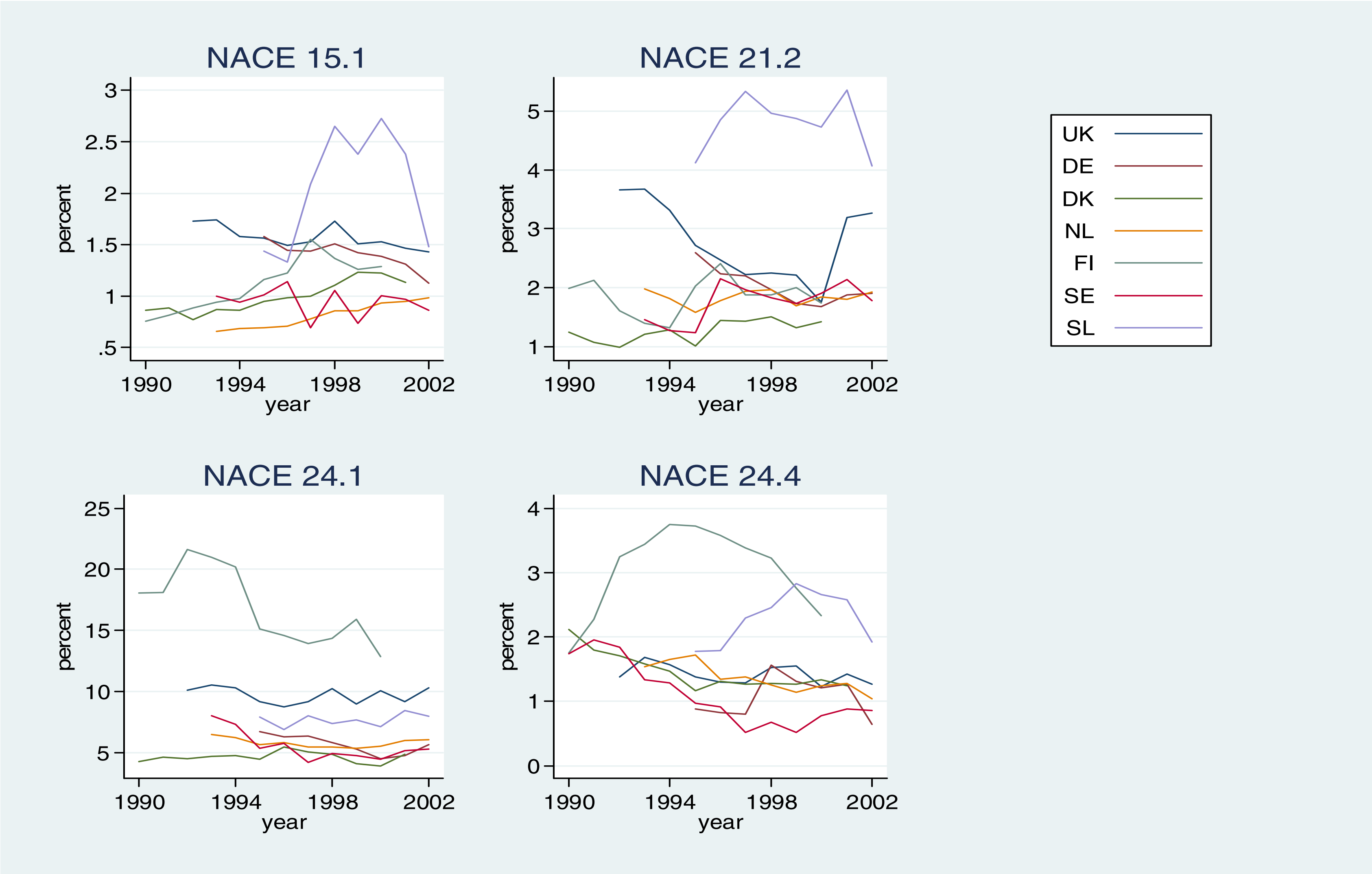


Figure 2.9(a) Energy share of total costs by country and sector (15.1 – 24.4)

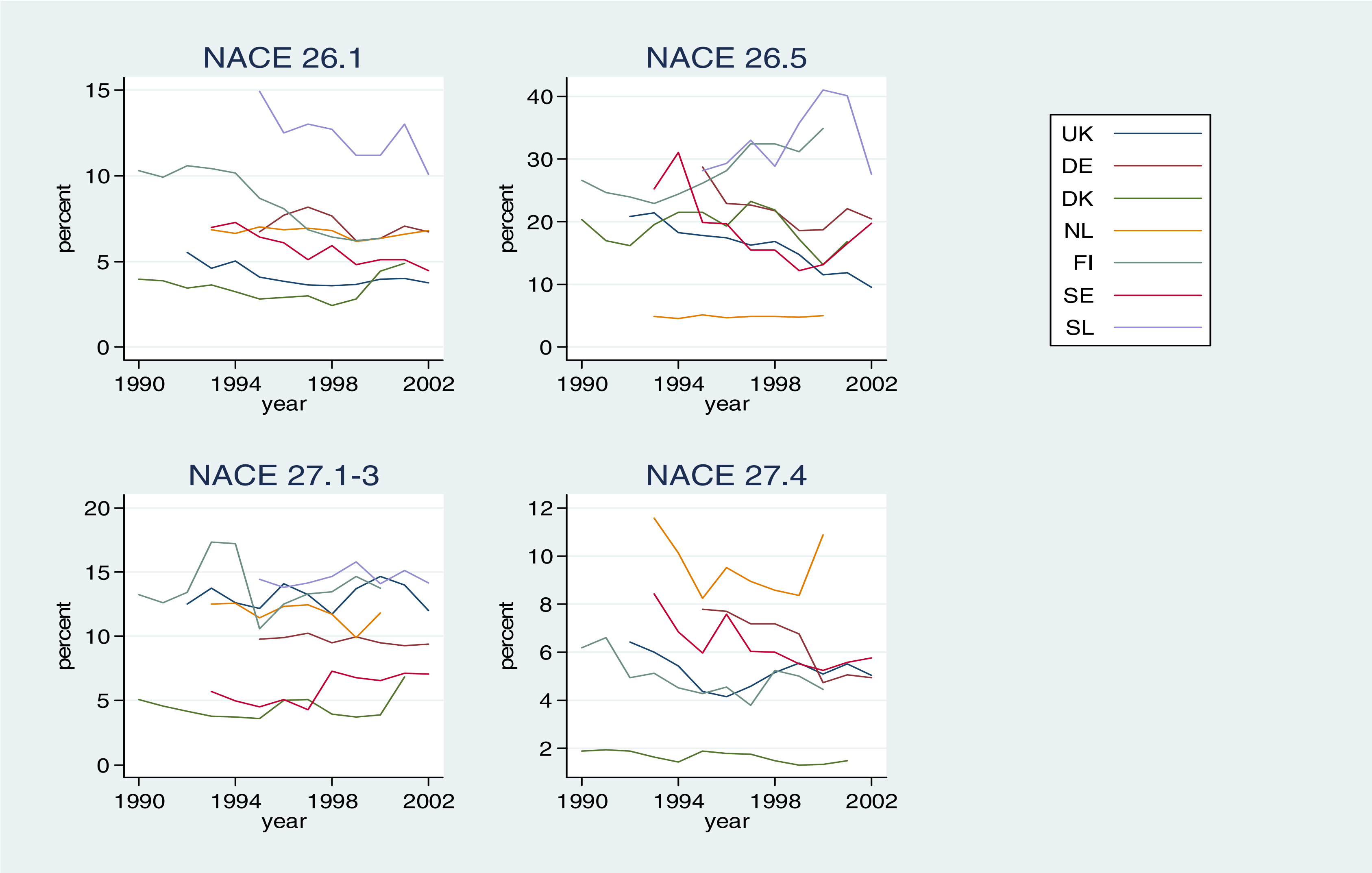


Figure 2.9(b) Energy share of total costs by country and sector (26.1 – 27.4)

3. Competitiveness indicators

A firm loses competitiveness if its cost of production rises faster than its competitors', or if it falls more slowly. Similarly, at the aggregate level, a sector in one country becomes less competitive if the production costs of its constituent firms rise faster (on average) than those in other countries, or fall more slowly. In theory therefore, changes in sectoral competitiveness can be measured directly by comparing the changes in production costs of firms in all competing countries. Unfortunately, in practice there are a number of problems with this direct approach.

In many sectors there may be no meaningful unit of measurement for aggregate output (even at the firm level), making the definition of unit production cost problematic. While it is possible to use the monetary value of gross output or gross value added (in constant prices) as a proxy for physical output, the strength of the correlation between the measures is open to question[13]. Even for sectors where there is a meaningful unit of measurement for output, data may not be (publicly) available for all – or indeed any – of the competing countries. Furthermore, where data does exist, it will usually only be available at an aggregate level, not for individual firms.

Consequently, the direct assessment of changes in competitiveness is likely to be either unreliable (at best), or impossible (at worst). What is needed therefore is a "proxy variable" (or set of variables) whose movements are closely related with changes in competitiveness, but that does not suffer from these practical problems. Four potential "indicators" are considered. These are:

- share of global production
- import intensity
- export intensity
- sector profitability (as % of sales)

There is an intuitive rationale for selecting these variables as indicators. If a sector's competitiveness improves one might expect its share of global production, export intensity and profitability all to increase, and its import penetration to fall; with the opposite being the case if it deteriorates. In the following analysis, the validity of these intuitive expectations – and hence the validity of the indicators – is assessed within the framework of a formal theoretical model.

The analysis is in four parts. In the first part, the model is defined and expressions for the basic model variables (e.g. sales, market shares, etc.) are derived. In the second part, the change in a sector's competitiveness is formally defined in terms of a necessary and sufficient condition. Comparison of this condition with equivalent conditions that are derived in the third part of the analysis for movements in the four indicators provides an assessment of the extent to which they reflect changes in competitiveness. Finally, the analytical results are illustrated using a simple numerical simulation.

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[13] See Freeman *et a*l (1997); Worrell *et al* (1997); Bernard *et al* (2002)..

3.1 Model definition

A homogeneous product is produced by firms based in <u>sectors</u> j = 1, … J and is purchased by consumers based in <u>markets</u> k = 1, … K; where both sectors and markets are defined geographically. For simplicity it is assumed that there is a single sector and a single market for each country in the world, although this does not have to be the case. Consequently the number of markets is equal to the number of sectors (i.e. J = K); with each sector having a "home market" and K-1 "export markets".

In all sectors, firms have constant unit costs of production (c_i^j) and a fixed cost (F_i^j), both of which are firm-specific. In addition, they incur market-specific constant unit transportation costs (r^{jk}) which are assumed to be the same for all firms in a particular sector. It is assumed that the transportation costs are equal to zero for all home-market sales.

Table 3.1 provides definitions of the basic model variables. The price in each market is determined by a market-specific linear inverse demand function: $P^k = a^k - b^k X^{\cdot k}$. Three definitions of average production cost are used in the analysis. These are:

- average of unit production costs for firms in sector $j \in J$

$$c^j = \frac{1}{N^j}\left(\sum_{i \in I^j} c_i^j\right) \qquad \text{… (1a)}$$

- average production cost for sales in market $k \in K$ by sector $j \in J$ [14]

$$\check{c}^{jk} = \frac{1}{X^{jk}}\left(\sum_{i \in I^j} c_i^j x_i^{jk}\right) \qquad \text{… (1b)}$$

- average of unit production costs for all firms

$$\hat{c} = \frac{1}{N}\left(\sum_{j \in J}\sum_{i \in I^j} c_i^j\right) = \frac{1}{N}\left(\sum_{j \in J} N^j c^j\right) \qquad \text{… (1c)}$$

Under the assumption of sector-specific unit transportation costs, within each sector firms with lower unit production costs will have higher market shares in all markets. Consequently, it follows that $c^j \geq \check{c}^{jk}$ for all $k \in K$, with equality only occurring (in all markets) if all of the firms in the sector have identical unit costs of production. More typically, the average of the unit production costs will be strictly greater than the average production costs of the sector's sales in every market, and this is assumed to be the case in the following analysis.

[14] If the sales of each firm in the sector are the same, then the average of their unit production costs is equal to the average production cost of sales in each market (i.e. $c^j = \check{c}^{jk}$ for all $k \in K$).

Table 3.1 Definition of variables

Variable	Definition
x_i^{jk}	sales in market $k \in K$ for firm $i \in I^j$ based in sector $j \in J$
X^{jk}	aggregate sales in market $k \in K$ for sector $j \in J$
$X^{\cdot k}$	aggregate sales in market $k \in K$
$X^{j\cdot}$	aggregate sales / production of sector $j \in J$
X	total aggregate sales / production
σ^{jk}	share of sales in market $k \in K$ for sector $j \in J$
$\sigma^{j\cdot}$	share of total sales / production for sector $j \in J$
R^{jk}	aggregate revenue in market $k \in K$ for sector $j \in J$
$R^{j\cdot}$	aggregate revenue for sector $j \in J$
γ^{jk}	share of total revenue for sector $j \in J$ received in market $k \in K$
π^{jk}	aggregate profitability of sector $j \in J$ in market $k \in K$
$\pi^{j\cdot}$	aggregate profitability of sector $j \in J$
N^j	number of firms in sector $j \in J$
N	total number of firms
$\rho^{j\cdot}$	share of total number of firms for sector $j \in J$
c_i^j	unit production cost of firm $i \in I^j$ based in sector $j \in J$
F_i^j	fixed costs of firm $i \in I^j$ based in sector $j \in J$
F^j	aggregate fixed costs for sector $j \in J$
r^{jk}	unit transportation cost incurred by firms in sector $j \in J$ for market $k \in K$
P^k	price in market $k \in K$

It is assumed that all firms participate (i.e. have strictly positive sales) in all markets, and that in each market firms compete as Cournot oligopolists. Under these assumptions, it follows directly that:[15]

$$X^{jk} = \frac{1}{b^k}\left(\frac{N^j}{N+1}\right)\left(a^k - (N+1)(c^j + r^{jk}) + N(\hat{c} + r^k)\right) \qquad \text{… (2a)}$$

$$X^{\cdot k} = \left(\frac{N}{N+1}\right)\left(\frac{a^k - \hat{c} - r^k}{b^k}\right) \qquad \text{… (2b)}$$

$$P^k = \left(\frac{a^k}{N+1}\right) + \left(\frac{N}{N+1}\right)(\hat{c} + r^k) \qquad \text{… (2c)}$$

where $r^k = \frac{1}{N}\left(\sum_{j\in J} N^j r^{jk}\right)$ is the average unit transportation cost for market $k \in K$.

[15] Annex A provides details of the derivation of these expressions and of all the other expressions used in this section .

It is also straightforward to derive the following expressions for a sector's shares of individual and its share of global production. It should be noted that – unlike the preceding expressions for quantities and prices – these expressions include endogenous sales / production levels as well as exogenous parameters. However, the simple form of the expressions is useful in the later analysis[16].

$$\sigma^{jk} \equiv N^j \left(\left(\frac{a^k - c^j - r^{jk}}{b^k X^{\cdot k}} \right) - 1 \right) \qquad \text{… (3a)}$$

$$\sigma^{j\cdot} \equiv N^j \left(\sum_{k \in K} \left(\frac{a^k - c^j - r^{jk}}{b^k X} \right) - 1 \right) \qquad \text{… (3b)}$$

3.2 Change in sectoral competitiveness

The competitiveness of a firm is defined to improve if the increase in its unit production cost is less than the average increase in unit production costs of all other firms, or if the reduction in its unit production cost is greater than average reduction of the other firms. Conversely, it will lose competitiveness if its unit production cost increases by more than its competitors, or reduces by less.

This definition can be extended to the sectoral level, with a sector gaining competitiveness if the average increase (decrease) in the unit production costs of its constituent firms is less (greater) than the average increase (reduction) of firms in all other sectors, and losing competitiveness if the reverse is true[17]. Formally, the necessary and sufficient condition for sector $j \in J$ to gain (lose) competitiveness is that:

$$\frac{1}{N^j} \left(\sum_{i \in I^j} \Delta c_i^j \right) \quad < (>) \quad \frac{1}{(N - N^j)} \left(\sum_{i \notin I^j} \Delta c_i^j \right)$$

which can be re-arranged to yield the following condition:

$$\Delta c^j - \Delta \hat{c} \quad < (>) \quad 0 \qquad \text{… (C1a)}$$

For small changes in unit costs, the condition can be expressed in terms of differentials:

$$dc^j - d\hat{c} \quad < (>) \quad 0 \qquad \text{… (C1b)}$$

3.3 Potential indicators of changes in sectoral competitiveness

In the introduction to this section, four potential competitiveness indicators were identified:

[16] Eliminating the endogenous sales / production variables would yield much more complex expressions. This is not necessary for the purposes of this analysis, and it is easier to work with these "mixed" expressions.

[17] By definition, the average change in unit production costs of constituent firms (i.e. $\Sigma(\Delta c_i^j)/N^j$) is the same as the change in the average of the unit production costs . (i.e. $\Sigma(\Delta c_i^j/N^j)$).

- Share of global production
- Import intensity in home market
- Export intensity
- Profitability as a percent of sales

These are considered in turn below to determine whether there is a predictable relationship between movements in the indicator and changes in competitiveness (as defined above).[18]

In addition to changes in unit production costs, the analysis allows for the possibility that markets may be growing or shrinking over time. This is achieved by allowing the choke price in each market (a^k) to vary independently, while keeping the slope of the inverse demand curve (b^k) constant[19]. All of the other exogenous parameters in the model are held constant. In particular, the number of firms in each sector is fixed – i.e. there is no entry or exit as a result of the changes in unit costs.

a) Share of global production

The following expression can be derived for the change in the share of global production for sector $j \in J$ (see Annex A for derivation):

$$d\sigma^j \quad = \quad \left(\frac{N^j}{X}\right)\left[\,(d\hat{a}^k - dc^j) \; - \; \left(1+\frac{\sigma^j}{N^j}\right)\left(\frac{N}{N+1}\right)(d\hat{a}^k - d\hat{c})\,\right]\sum_{k\in K}\left(\frac{1}{b^k}\right) \qquad \ldots (4)$$

$$\text{where } d\hat{a} = \left(\sum_{k\in K}\frac{da^k}{b^k}\right) \Big/ \left(\sum_{k\in K}\frac{1}{b^k}\right)$$

It follows directly that the necessary condition and sufficient condition for share of global production of sector $j \in J$ to increase (decrease) is that:

$$dc^j - d\hat{c} \qquad < (>) \qquad \frac{1}{N+1}\left(1 - \frac{\sigma^{j\cdot}}{\rho^j}\right)(d\hat{a} - d\hat{c}) \qquad \ldots (C2)$$

The expression on the right-hand side of condition (C2) is not generally equal to zero – only being so if the sector's share of global production is equal to its share of the total number of firms; or if the weighted average change in the choke prices in the various markets is equal to the average change in the unit costs of all firms. Neither of these two conditions is likely to be true in general, although the sector shares of global production and number of firms will be similar if there is little variation in the average scale of firms between sectors. In general, the expression may be positive or negative.

[18] As was noted in the introduction, with the exception of import intensity, one might expect each of these indicators to increase if the sector becomes more competitive, and to decrease if it loses competitiveness. For import intensity, the opposite might be expected to be the case.

[19] Thus, the (inverse) demand curve may shift outwards (or inwards) over time, but the slope does not change.

However, if the total number of firms is relatively large, then the right-hand side of (C2) will be approximately equal to zero. For most sectors this is likely to be the case and hence the direction of change of a sector's share of global production is a good indicator of its change in competitiveness. If a sector gains competitiveness, its share of global production increases; if it loses competitiveness, it declines (see Figure 3.1[20]).

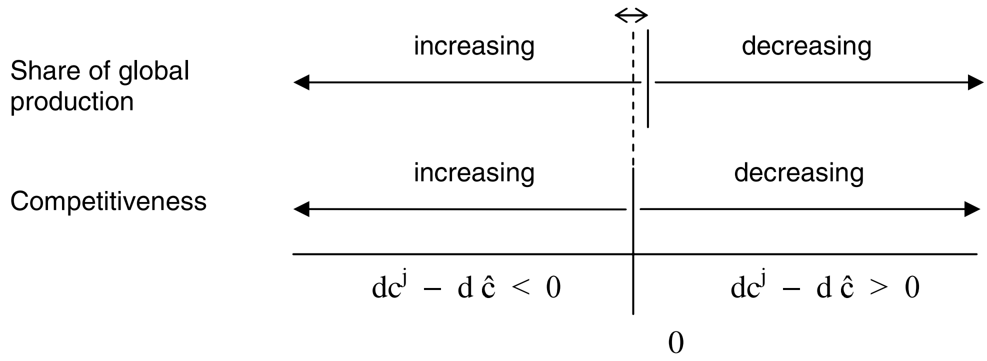


Figure 3.1: Changes in competitiveness and global market share

Import intensity of home market

The import intensity for the home market of sector $j \in J$ is identically equal to one minus the sector's market share, i.e. $\mu^{jj} \equiv 1 - \sigma^{jj}$. The following expression can be derived for the change in the import intensity share of global production for sector $j \in J$ (see Annex A for derivation):

$$d\mu^{jj} = -\left(\frac{N^j}{b^j X^{\cdot j}}\right)\left[(da^j - dc^j) - \left(1+\frac{\sigma^{jj}}{N^j}\right)\left(\frac{N}{N+1}\right)(da^j - d\hat{c})\right] \quad \ldots (5)$$

It follows directly that the necessary condition and sufficient condition for import intensity of the home market for sector $j \in J$ to decrease (increase) is that:

$$dc^j - d\hat{c} \quad < (>) \quad \frac{1}{N+1}\left(1 - \frac{\sigma^{jj}}{\rho^j}\right)(da^j - d\hat{c}) \quad \ldots (C3)$$

As before, the right-hand side of condition (C3) is only equal to zero if the sector's home market share is equal to its share of the total number of firms, or if the change in the choke price in the home market is equal to the average change in the unit costs of all firms. Unlike the previous indicator, one might expect a sector's share of its own market to be significantly greater than its share of total firms (implying that the middle term is negative). Furthermore, unless the change in the choke price is the same for all markets, the magnitude of the final term in (C3) will – by definition – be greater than the corresponding term in (C2) for some of the sectors (but smaller for others). Consequently, the absolute magnitude of the right-hand side of (C3) is likely to be larger than for (C2) – at least for some sectors. However, again if the total number of firms is relatively large, then it will be approximately equal to zero, and hence the direction of change of the import intensity of a sector's home market also provides a good indicator of its change in competitiveness. If a sector gains competitiveness, the import intensity of its home market decreases; if it loses competitiveness, it increases (see Figure 3.2).

[20] In Figures 2.1 – 2.3 it is assumed that the value of the right-hand side of the condition is positive. However, this need not necessarily be the case.

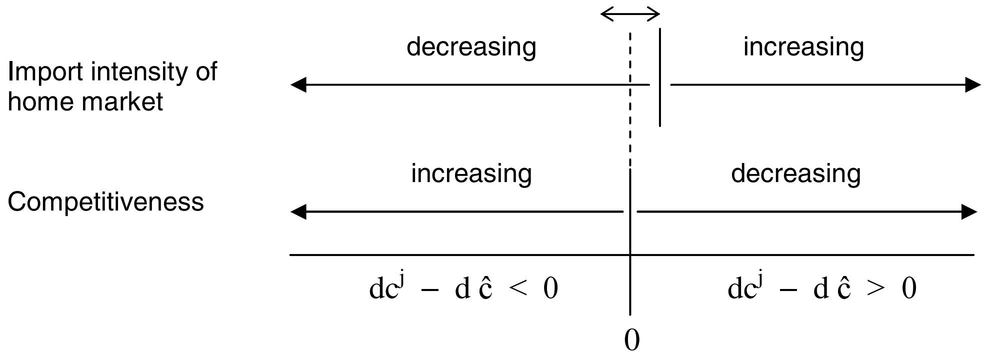


Figure 3.2: Changes in competitiveness and import intensity of home market

Export intensity

The export intensity for sector $j \in J$ is identically equal to one minus the share of the sector's production sold in its home market, i.e.

$$\xi^j \equiv 1 - \left(\frac{X^{jj}}{X^{j\cdot}} \right)$$

The following expression can be derived for the change in the import intensity share of global production for sector $j \in J$ (see Annex 1 for derivation)

$$d\xi^j = \left(\frac{(1-\nu^j)N^j}{X^{j\cdot}} \right) \left(\sum_{k \in K} \frac{1}{b^k} \right) \left[(d\hat{c} - dc^j) - \left(\frac{1}{N+1} \right) (d\hat{c} - d\tilde{a}^j) \right] \quad \ldots (6)$$

where

$$\nu^j = \eta^j + \xi^j$$

$$\eta^j = \frac{1}{K} \left(\frac{1}{b^j} \Big/ \left(\sum_{k \in K} \frac{1}{b^k} \Big/ K \right) \right)$$

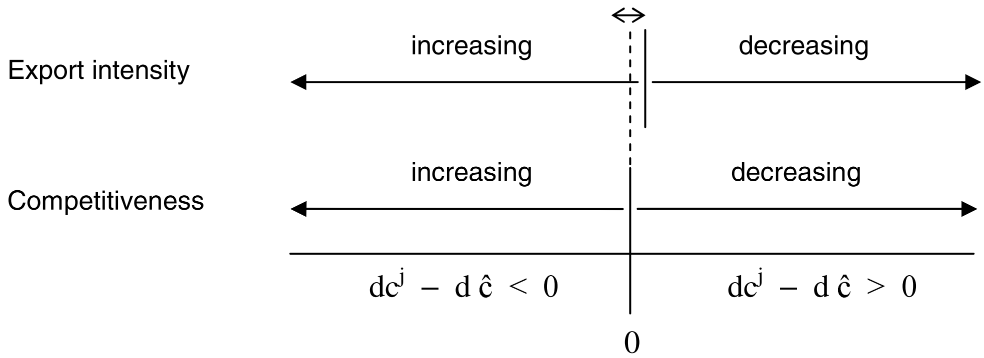
$$d\tilde{a}^j = [\,(1-\xi^j)\, d\hat{a} - \eta^j\, da^j\,] / (1-\nu^j)$$

The necessary and sufficient condition for the export penetration of sector $j \in J$ to increase (decrease) is that:

$$dc^A - d\hat{c} \begin{cases} < (>) \left(\dfrac{1}{N+1} \right) (d\tilde{a}^A - d\hat{c}) & \text{if} \quad \nu^j < 1 \quad \ldots \text{(C4a)} \\[2ex] > (<) \left(\dfrac{1}{N+1} \right) (d\tilde{a}^A - d\hat{c}) & \text{if} \quad \nu^j > 1 \quad \ldots \text{(C4b)} \end{cases}$$

Again, if the total number of firms is large, the value of the expression on the right-hand side of the inequality is approximately equal to zero. However, as can be seen in Figure 3.3, the relationship between changes in export intensity and changes in competitiveness is not as straightforward as for the previous two indicators.

a) $\nu^j < 1$



b) $\nu^j > 1$

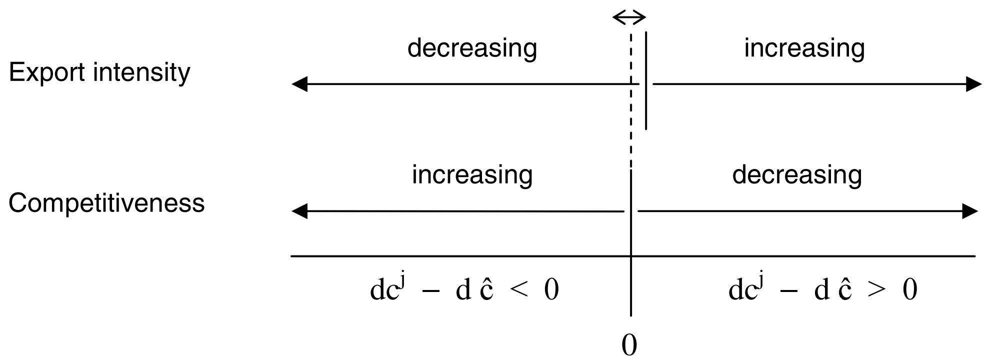


Figure 3.3: Changes in competitiveness and export intensity

If the value of the parameter ν^j is less than one, then a sector's export intensity increases as it gains competitiveness and declines as it becomes less competitive. However, if the value of this parameter is greater than one, the opposite is the case. The value of ν^j is equal to the level of the export penetration (ξ^j) plus a parameter (η^j) which is determined by the slope of the demand curve in the sector's home market relative to the other markets and the total number of markets. If there are a large number of markets with similar slopes for their respective demand curves, then the value of ν^j will be approximately equal to the sector's export penetration. In most cases this will be significantly less than one; in which case the sector's export penetration increases as it gains competitiveness. However, if there are only a few markets (countries) with significant variation in the slopes of demand curves, export intensity may decline. Consequently, care should be taken in using movements in export intensity as an indicator of changes in competitiveness.

Profitability as percent of sales

The overall profitability of sector $j \in J$ is equal to the weighted average of its (operating) profitability in each market, less aggregate fixed costs divided by total sector revenue; where the weights are equal to the markets' respective shares of total sector revenue.

$$\pi^j \quad = \quad \sum_{k\in K} \pi^{jk} \gamma^{jk} \; - \; \left(\frac{F^j}{R^{j\cdot}} \right)$$

The total differential is:

$$d\pi^j \quad = \quad \sum_{k\in K} d\pi^{jk} \gamma^{jk} \; + \; \sum_{k\in K} \pi^{jk} \, d\gamma^{jk} \; + \; \frac{1}{R^{j\cdot}} \left(\frac{F^j}{R^{j\cdot}} \right) dR^{j\cdot} \qquad \ldots (7)$$

Thus the change in the sector's overall profitability can be decomposed into three parts, due respectively to the change in the:

- sector's profitability in each of the markets (denoted $d\pi_P^j$);
- mix of the sector's revenues across the various markets (denoted $d\pi_M^j$);
- significance of the sector's fixed costs (denoted $d\pi_F^j$).

The following expression can be derived for the change in the profitability of sector $j \in J$ in market $k \in K$ (see Annex 1 for derivation)

$$d\pi^{jk} \quad = \quad \frac{(1-\pi^{jk})}{P^k} \left(\left(\frac{1}{N+1} \right) (d\,a^k - d\hat{c}\,) \; - \; (\,d\,c^j - d\hat{c}\,) \; - \; \Lambda^{jk} \right) \qquad \ldots (8a)$$

$$\text{where } \Lambda^{jk} \quad = \quad \left(\frac{\pi^{jk}}{1-\pi^{jk}} \right) d\,c^j \; + \; \left(\frac{1}{1-\pi^{jk}} \right) (\,c^j - \breve{c}^{jk}\,) \, \frac{d\,X^{jk}}{X^{jk}} \qquad \ldots (8b)$$

$$dX^{jk} \quad = \quad \frac{N^j}{b^k} \left(\left(\frac{1}{N+1} \right) (\,d\,a^k \; - \; d\,c^j\,) \; - \; (\,d\,c^j \; - \; d\hat{c}\,) \right) \qquad \ldots (8c)$$

The value of Λ^{jk} is not generally equal to zero and may be positive or negative. If the sector is gaining competitiveness, then the value of Λ^{jk} is unambiguously positive if its average unit production costs are increasing[21]. Similarly, the value of Λ^{jk} is unambiguously negative if it is losing competitiveness while its average production costs are falling. However, in the other two cases the sign of Λ^{jk} is ambiguous.

[21] Since $c^j > \breve{c}^{jk}$, the sign of the second term of Λ^{jk} is determined by the change in the sector's output. It is clear from (8c) that sales in every market increase (decrease) as the sector gains (loses) competitiveness.

The necessary and sufficient condition for profitability of sector $j \in J$ in country $k \in K$ to increase (decrease) is:

$$dc^{j} - d\,\hat{c} \quad < (>) \quad \left(\frac{1}{N+1} \right) (da^{k} - d\,\hat{c}) \; - \; \Lambda^{jk} \qquad \ldots \text{(C5a)}$$

Unlike the previous indicators, the right-hand side of condition (C5a) does not necessarily tend to zero as the number of firms increases. Depending on the value of Λ^{jk}, it may be significantly positive or significantly negative. Consequently, it is possible that a sector may suffer a fall in profitability in some (or all) of its markets when it gains competitiveness. Conversely, profitability may increase despite the sector losing competitiveness.

If production costs are homogeneous and the sector's production cost is increasing, then the expression on the right-hand side of (C5a) will be unambiguously negative and hence market profitability will only increase if the sector is gaining competitiveness (see Figure 2.4 below). Similarly, if its unit production cost is falling, then the expression will be unambiguously positive and hence market profitability will only fall if the sector is losing competitiveness. However, homogeneity of costs is a strong assumption that is unlikely to be justified in practice.

The impact of the change in the mix of the sector's revenues between markets is given by:

$$d\pi_{M}^{j} \quad = \quad \sum_{k \in K} \left(\frac{dR^{jk}}{R^{jk}} - \frac{dR^{j\cdot}}{R^{j\cdot}} \right) \varphi^{jk} \qquad \ldots (9)$$

$$\text{where } \varphi^{jk} \quad = \quad \gamma^{jk} \, (\pi^{jk} - \pi^{j\cdot})$$

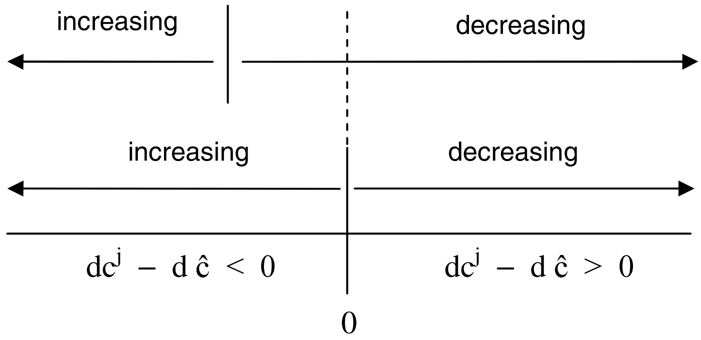
By definition, the values φ^{jk} ($k = 1, \ldots K$) sum to zero. The mix effect will be zero if there is no difference in the sector's profitability between markets, or if all markets experience the same growth in revenue. However, in general this will not be the case and the overall sign of the mix effect will depend on the relative percentage changes in revenue in each market. If revenue growth is greatest in markets with below average profitability, then the overall impact will be negative. If the reverse is true, it will be positive. The relative growth rates will depend on a range of factor (i.e. parameter values) and it does not follow that an increase in competitiveness will lead to greater (smaller) increases in revenue in more profitable markets. Consequently, there is no predictable relationship between changes in competitiveness and changes in profitability due to mix effects.

(homogeneous production costs)

a) Increasing average unit production cost

Market profitability

Competitiveness



b) Decreasing average unit production cost

Market profitability

Competitiveness

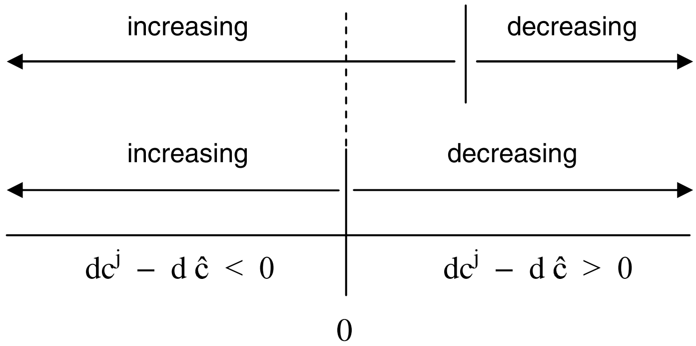


Figure 3.4: Changes in competitiveness and market profitability

Finally, the change in profitability due to the change in the significance of the aggregate fixed cost depends on the change in the sector's total revenue. This is reflected in the following expression for the "fixed cost effect" for sector $j \in J$ (see Annex A for derivation):

$$d\pi_F^j = \frac{1}{R^{j}}\left(\frac{F^j}{R^{j}}\right)\left[\sum_{k\in K} X^{jk}\, dP^k \left(1 + \left(\frac{P^k}{P^k - c^{jk} - r^{jk}}\right)\left(1 - \frac{dc^j}{dP^k}\right)\right)\right] \quad \ldots (10a)$$

In the special case where there are no changes to the values of the choke prices in any of the markets (i.e. $da^k = 0$ for all $k \in K$), this expression can be simplified to give:

$$d\pi_F^j = \frac{d\hat{c}}{R^{j}}\left(\frac{F^j}{R^{j}}\right)\left(\frac{N}{N+1}\right)\left[\sum_{k\in K} X^{jk}\left(1 + \theta^{jk}\left(1 - \left(\frac{N+1}{N}\right)\frac{dc^j}{d\hat{c}}\right)\right)\right] \quad \ldots (10b)$$

where $\theta^{jk} = \dfrac{P^k}{P^k - c^{jk} - r^{jk}} > 1$

In this special case, if $d\hat{c} > 0$ then a sufficient condition for the fixed cost effect to be positive (i.e. $d\pi_F^j > 0$) for sector $j \in J$ is that:

$$dc^j - d\hat{c} \quad < \quad -\left(\frac{1}{N+1}\right) d\hat{c} \qquad \text{… (C5b)}$$

Similarly, if $d\hat{c} < 0$, then a sufficient condition for the fixed cost effect to be negative (i.e. $d\pi_F^j < 0$) for sector $j \in J$ is that:

$$dc^j - d\hat{c} \quad > \quad -\left(\frac{1}{N+1}\right) d\hat{c} \qquad \text{… (C5c)}$$

However, while these conditions are sufficient, they are not necessary. Furthermore, they rely on the assumption that the markets are static (i.e. the choke prices do not change in any markets). In general, the overall impact on a sector's total revenues is unclear. They may fall in some (or all) of its markets when it is gaining competitiveness, and they may rise when it is losing competitiveness. So again there is no predictable relationship between changes in competitiveness and changes in profitability due to fixed cost effects.

Thus, in general all three components of the change in profitability can move in either direction as a sector gains or loses competitiveness. Only under a number of restrictive assumptions can changes in sectoral profitability provide a good indicator of changes in competitiveness.

3.4 Illustrative example

The analytical results presented above are now be illustrated by a simple numerical example in which there are three countries and firms are homogeneous within each sector (in terms of unit and fixed costs). Two cases are considered with different sets of parameter values. These are shown in Table 3.2, together with the resultant equilibrium values (before the cost changes) for the total sales, price and market shares in each of the three markets.

Table 3.2 Numerical example

a) Parameter values

Variable	Case A Country 1	Case A Country 2	Case A Country 3	Case B Country 1	Case B Country 2	Case B Country 3
N^j	500	800	500	500	800	500
c_i^j	2.0	2.4	1.7	2.0	2.4	2.2
F_i^j	0.3	0.3	0.3	1.0	1.0	1.0
a^k	900	5000	900	4000	600	1700
b^k	0.1	10	0.1	5.0	0.5	5.0

b) Equilibrium values before cost changes

Variable	Case A Market 1	Case A Market 2	Case A Market 3	Case B Market 1	Case B Market 2	Case B Market 3
X^k	8971	500	8971	799	1194	339
P^k	2.95	5.15	2.95	4.81	2.84	3.54
σ^{1k}	53.2%	26.5%	25.3%	35.2%	28.7%	30.6%
σ^{2k}	4.8%	44.0%	4.8%	38.3%	59.3%	30.0%
σ^{3k}	42.0%	29.5%	69.9%	26.5%	12.0%	39.4%

The numbers of firms in each sector is the same in each case, as is the common unit transportation costs for export sales (which is equal to 0.5, i.e. around 25% of unit production costs). Most of the other parameters differ between the two cases.

In Case A, the inverse demand curve for market 2 has a high choke price and a steep slope, while the other two markets have (identical) low choke prices and shallow slopes. This is reflected in the respective market sizes and prices; with market 2 being much smaller than the other two, and having a higher price. In each market, the home sector has the highest market share – this being particularly pronounced for market 3. In Case B the situation is reversed. The inverse demand curve for market 3 has the lowest choke price and the shallowest slope; with the result that it is now the largest market with the lowest price. While the dominance of the home sector is greater than in Case A for market 2, market shares are more evenly spread in the other two markets. Indeed, sector 2 now has the largest market share in market 1.

The impacts of changes in the sector's unit production costs on competitiveness, and on the four potential indicators are shown in Figure 3.5. In each case the choke prices for the respective markets are held constant (i.e. there is no market growth), while the changes in production costs result in a loss of competitiveness for sector 2, a gain in competitiveness for sector 3, and leave the competitiveness of sector 1 unchanged (NB: the line included on the unit cost chart represents the weighted average change in unit costs).

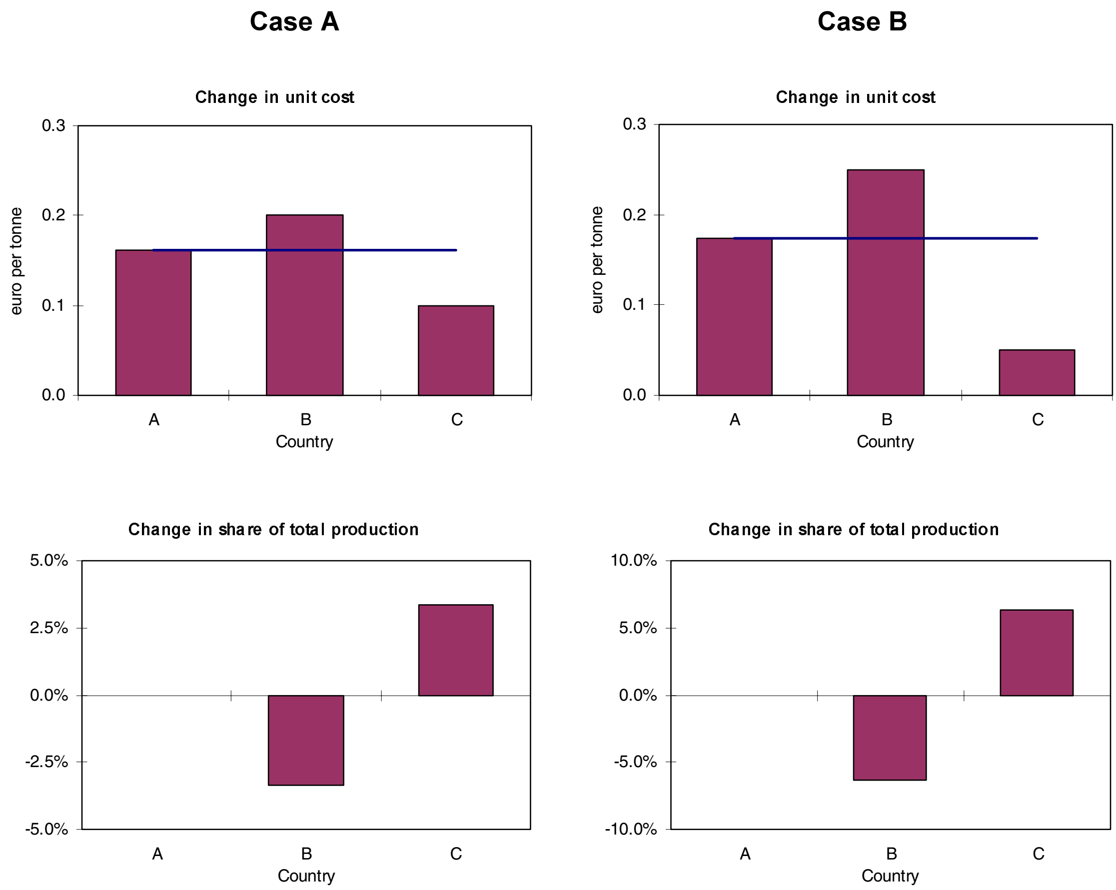


Figure 3.5 Impact of changes to unit production costs

Case A **Case B**

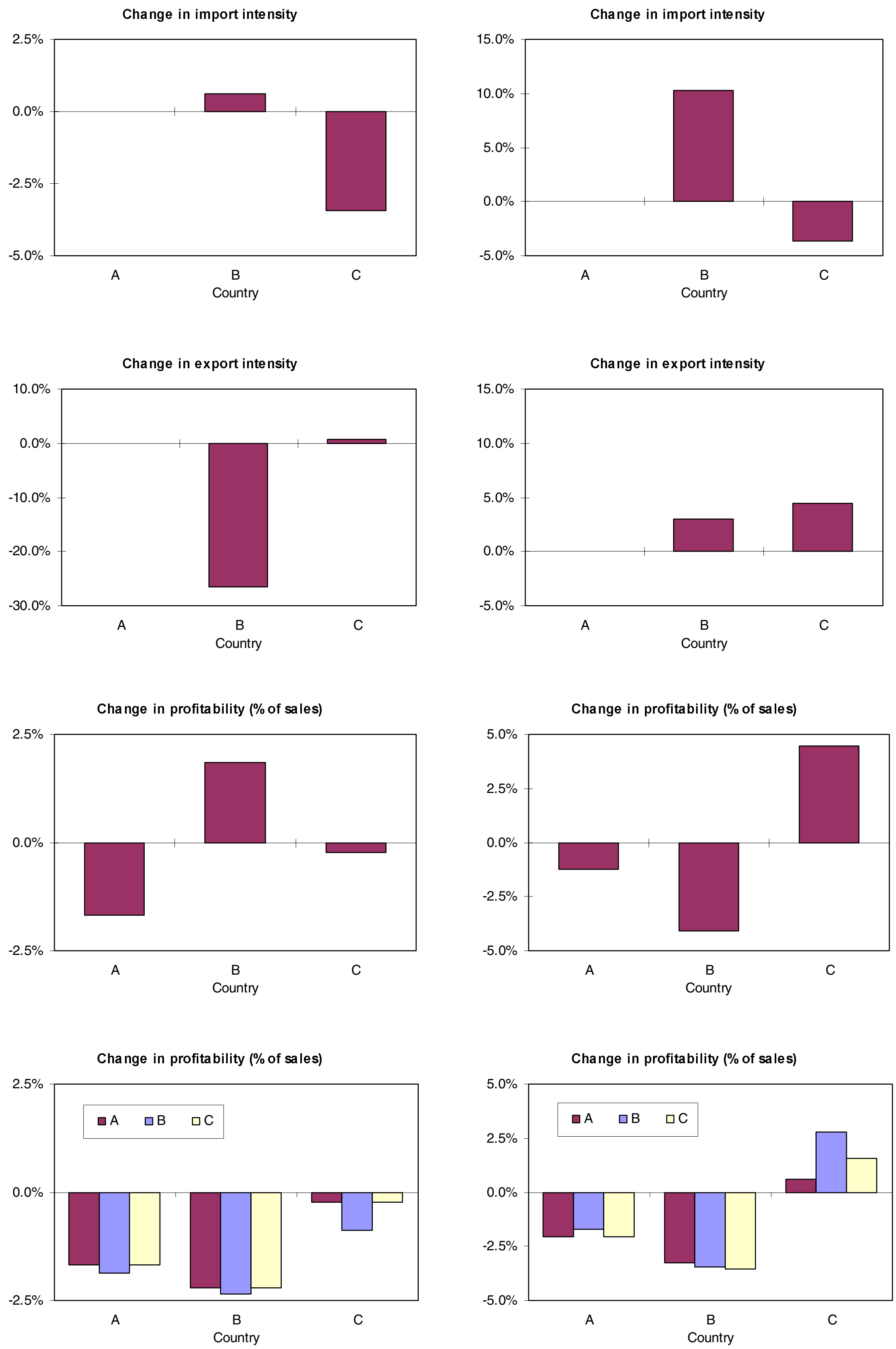


Figure 3.5 Impact of changes to unit production costs (continued)

For the first two indicators the changes are as one would expect. The share of global production increases for sector 3 and decreases for sector 2; while the import intensity of the home market declines for sector 2 and rises for sector 2. For both of the indicators, there is no change for sector 1.

For the other two indicators it is clear that the impacts of the cost changes depend on the parameter values. In Case A the changes in export intensity are directly related to the changes in competitiveness – albeit with only a small impact for sector 3. However, in Case B both sectors experience an increase in export intensity. The increase for sector 2 – which has suffered a loss of competitiveness – arises because of the small number of markets in this example and the relatively extreme variation in the slopes of the demand curves, which result in a value of 0.667 for η^2. Since the export intensity of the sector (before the cost changes) is 0.365, this is sufficiently large to push the value of ν^2 above one[22]. As is shown in Figure 3.4, when this is the case, a loss of competitiveness is associated with an increase in export intensity.

In Case B, the changes in sector profitability are directly related to the changes in competitiveness. However, in Case A the direction of change in the overall profitability of both sectors is reversed, although for different reasons. For sector 2, profitability declines in every market, while a halving of total revenue means that the fixed cost effect is also negative. However, the impact on revenue varies considerably between markets, with revenue actually increasing in the sector's most profitable market (its home market). The resultant positive mix effect dominates the other two impacts, causing the sector's overall profitability to rise. Profitability also declines in every market for sector 3, despite its increase in competitiveness. This is because the improvement in its competitiveness (i.e. $dc^3 - d\hat{c}$) is insufficient to overcome the relatively large values for Λ^{3k} that arise from its high levels of profitability in the three markets (see condition C5.a)[23]. The mix effects are insignificant for this sector and while its total revenue increases by around 10%, the beneficial fixed cost effect is not sufficient to offset the reductions in market profitability.

3.5 Summary

In this section, the capabilities of four potential "indicators" to represent changes in sectoral competitiveness have been assessed in the context of a theoretical model. As with any exercise of this type, the results and conclusions of the analysis depend on the underlying structure and assumptions of the model. While the model that has been used is relatively general in some respects and captures many of the salient features of the issue, it is clearly a simplification of reality[24]. In particular, it assumes that the firms produce a single homogeneous product with constant unit costs of production; that they all participate in all markets; and that demand is for the product is linear in all markets. Consequently, the results of the analysis should be seen as providing guidance regarding the choice

[22] The export intensity of sector 3 is double that of sector 3 (being equal to 0.726). However, the value of η^3 is only 0.167, meaning that the value of ν^3 is less than one.

[23] For example, the sector's profitability in market 2 prior to the cost changes is 67%. Consequently, the value of $\Lambda^{32} = 0.1 \times (0.67 / (1 - 0.67) = 0.2$, while the change in competitiveness is only -0.062.

[24] It is consistent with the model underlying the analysis in WP2 regarding the ability of sectors to pass on increases in production costs in price rises. In this model the proportion of any increase in its unit production cost that a sector is able to pass on is (approximately) equal to its share of the total number of firms producing the product.

and interpretation of indicators to assess changes in competitiveness, rather than definitive predictions of what would happen to these variables in practice.

Bearing this caveat in mind, there do appear to be differences in the capabilities of the different indicators to represent changes in competitiveness. Provided that the total number of firms is relatively large (which is likely to be the case in practice), changes in <u>share of global production</u> and changes in <u>import intensity</u> both provide good indicators of changes in competitiveness. If a sector's competitiveness improves, its share of production increases while the import intensity of its home market declines. If it deteriorates then the opposite is the indicators move in the opposite directions.

Changes in <u>export intensity</u> can also provide a good indicator of changes in competitiveness, but only if one can be sure whether the value of the parameter ν is less than, or greater than one. If this is not known, then one cannot be sure whether increases in export intensity reflect an improvement or a deterioration of competitiveness. The value of the parameter is equal to the sum of two components: the sector's export intensity; and a factor reflecting the relative slope of the demand curve in the sector's home market compared to all markets. In practice, only the value of the first of these two components will be known. However, in most cases the value of the second component is likely to be small. Consequently, if the sector's export intensity is relatively low (say below 50%), it is likely that the overall value of the parameter will be less than one. In this case, an improvement in a sector's competitiveness will be reflected in an increase in its export intensity.

Finally, changes in sector profitability do not – in general – provide a good indicator of changes in competitiveness. One cannot even be sure of the relationship between changes in competitiveness and changes in profitability in individual markets. Furthermore, the mix effects and fixed cost effects induced by the change in competitiveness can be in either direction, making it impossible to draw any reliable conclusions about changes in competitiveness from changes in sector profitability.

4. Competitiveness trends

This section considers whether there is any evidence that competitiveness deteriorated over the period 1990-2002 for any of the seven ETR countries in the selected sectors. The assessment is based on the following direct and indirect indicators of competitiveness, which were identified and discussed in the previous section.

- *Relative unit costs*

  By definition, a country loses (gains) competitiveness in a particular sector if its unit costs rise by more (less) than the average unit costs of other countries. Ideally trends in the unit cost for each country would be compared to the trend for the global average unit cost or, failing that, the trend for some large group of countries (e.g. OECD or EU25 member states). Unfortunately, data was not available for either of these comparators and consequently the average unit cost for the EU15 member states has been used as a proxy. This was calculated as the sum of sector total intermediate costs and labour costs in current prices, divided by sector gross value added in constant prices[25].

- *Import intensity*

  According the theoretical model, import intensity should be expected to rise (fall) if a country loses (gains) competitiveness. Intensity values were calculated as the ratio of total imports of goods and services to domestic demand (which is equal to total output less net exports) using the data for the component variables provided in the COMETR datasets.

- *Share of global production*

  According the theoretical model, global market share should be expected to fall (rise) if a country loses (gains) competitiveness. Unfortunately, data on global market shares was not available. However, provided that the case-study countries' combined share of world production is fairly stable over the study period, it can be shown that there is a direct correlation between a country's share of global production and its relative index of production.[26] For some sectors (e.g. meat processing), this assumption is more acceptable than for others (e.g. ferrous metals production,). However, given the data limitations the use of the index of production was deemed the most suitable proxy. The relative production index for a particular country is calculated by dividing its own index of production by the weighted average production index for all case-study countries; where the weights are equal to the countries' respective shares of total sector GVA in 2000.

[25] All three series were obtained from EUROSTAT (v13110, v13310, v99150). Missing values were interpolated. The total production series was only available from 1995 onwards. It was backcast to 1990 by assuming a constant ratio of total production costs to gross value added.

[26] For details on this correlation see the data appendix.

- *Export intensity*

  As was discussed in the previous section, the relationship between changes in competitiveness and changes in export intensity depend on value of the parameter ν^j, which in turn depends on the level of export intensity and the relative slopes of the demand curves in the different countries. If the value of ν^j is less than one, then a sector's export intensity increases as it gains competitiveness and declines as it becomes less competitive; with the opposite being the case if the value of the parameter is greater than one. For the purposes of this analysis, it is assumed that the first case holds if the export intensity is smaller than 50%; while the second case holds if it is greater than 80%[27]. However, the choice of these thresholds is fairly arbitrary and hence caution should be exercised when interpreting trends in export intensity for sectors that are close to these values. Export intensity is calculated as the ratio of total exports of goods and services to total output, using the data provided in the COMETR datasets.

- *Profitability as a percent of sales*

  Gross operating surplus as a percentage of total output is used for this indicator; with data for the two components being taken from the COMETR datasets. However, as was discussed in the previous section the relationship between changes in competitiveness and changes in profitability is not straightforward and hence it is not possible to draw any reliable conclusions from changes in sector profitability. Thus, while the indicator is included for information, it is not used as part of the assessment.

Time-series charts are provided for each indicator. However, the volatility of the data means that it is not possible to identify changes from one year to the next, or to discern any changes due to the introduction of the ETRs in the respective countries. Consequently the focus of the analysis is on identifying trends in the data (or lack thereof), rather than analysing year-to-year movements. To this end, a table is included for each sector, identifying those indicators that have statistically significant positive, or negative, trend-lines[28]. Note that the terms 'positive' and 'negative' here refer to the slope of the lines. Depending on the indicator, a positive slope may not necessarily represent an improvement in competitiveness. For example, an upward trend for import intensity would be consistent with a deterioration of competitiveness.

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[27] If there are a large number of markets with similar slopes for their respective demand curves, then the value of ν^j will be approximately equal to the sector's export penetration.

[28] Linear trends were fitted to the indicator series. Only trends that were significant at the 10% level or higher were reported.

4.1 Meat and meat products (NACE 15.1)

The meat products sector is the only sector where relative unit costs are either stable or falling over the study period, with unit costs in the Netherlands, Finland and Sweden falling faster than average EU15 unit costs. The only country where this is not the case is the United Kingdom. There is a general upward trend in import intensity, with only Germany experiencing a slight decline. In contrast, export intensity is fairly stable in most countries, although there was a significant increase for Denmark after 1999. For relative production there is no general pattern; the indicator rising for the Netherlands and Sweden, but falling for Denmark and the United Kingdom.

Table 4.1 identifies those indicators that have statistically significant trends in each of the seven countries; with indicators shaded pink if they are consistent with an improvement in competitiveness and blue if they are consistent with a decline. A noted above, if a country's export intensity lies in the range 60%-80% (as is the case with Denmark in this sector), then it is not possible infer anything about the change in competitiveness from the slope of the trend-line. The final column of the table shows the direction of change for competitiveness that is implied by the indicators. Consistency between at least three of the four indicators is required before it is inferred that there was a change in competitiveness over the study period.

Table 4.1 Summary of trends

Country	Relative Unit Cost	Import intensity	Relative Production	Export intensity	Overall
DE		-		+	
DK		+	-	+	
NL	-	+	+	+	Gain
FI	-	n.a.			
SE	-	+	+		
SL			n.a.		
UK	+	+	-	-	Loss

Note: No data available for import intensity for Finland or for index of production for Slovenia.

The indicators suggest that competitiveness improved for the Netherlands between 1990 and 2002, but deteriorated for the United Kingdom (where all four indicators point in the same direction). For Slovenia, none of the available indicators showed any significant change. For the other four countries, there were insufficient consistent indicators to draw any conclusions.

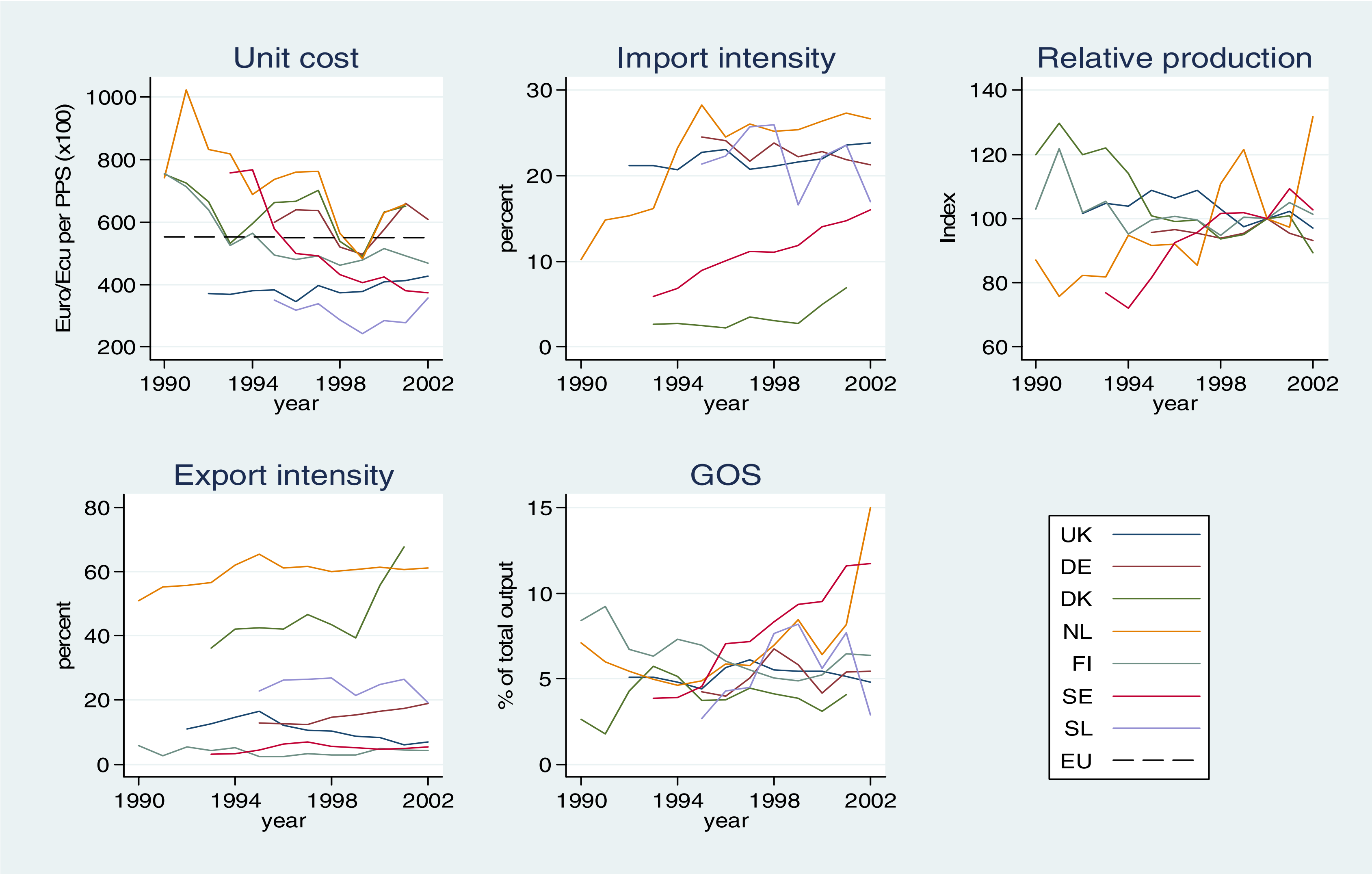

Figure 4.1 Indicator series for NACE 15.

4.2 Paper and paper products (NACE 21.2)

In the paper products sector, relative unit costs show a significantly positive trend in all of the countries over the study period except Finland and Slovenia. There is no clear pattern for the two trade intensity indicators, with increases for some countries and decreases for others. The dramatic reduction in both intensities between 1994 and 1995 for Sweden suggests that there may be a break in the trade date time-series between these years. The index of production in Finland and Sweden increases relative to the sector average over the study period, but falls in the United Kingdom.

Table 4.2 Summary of trends

Country	Relative Unit Cost	Import intensity	Relative Production	Export intensity	Overall
DE	+	+		-	Loss
DK	+	-			
NL	+	+		+	
FI		n.a.	+	-	
SE	+	-	+	-	
SL			n.a.	+	
UK	+	+	-	+	Loss

Note: No data available for import intensity for Finland, or for index of production for Slovenia

The indicators suggest that competitiveness deteriorated between 1990 and 2002 for Germany and for the United Kingdom; with rising unit costs and import intensity being supported by falling export intensity in Germany and declining relative production in the United Kingdom. For the other five countries, there are insufficient consistent indicators to make any inferences about changes in competitiveness.

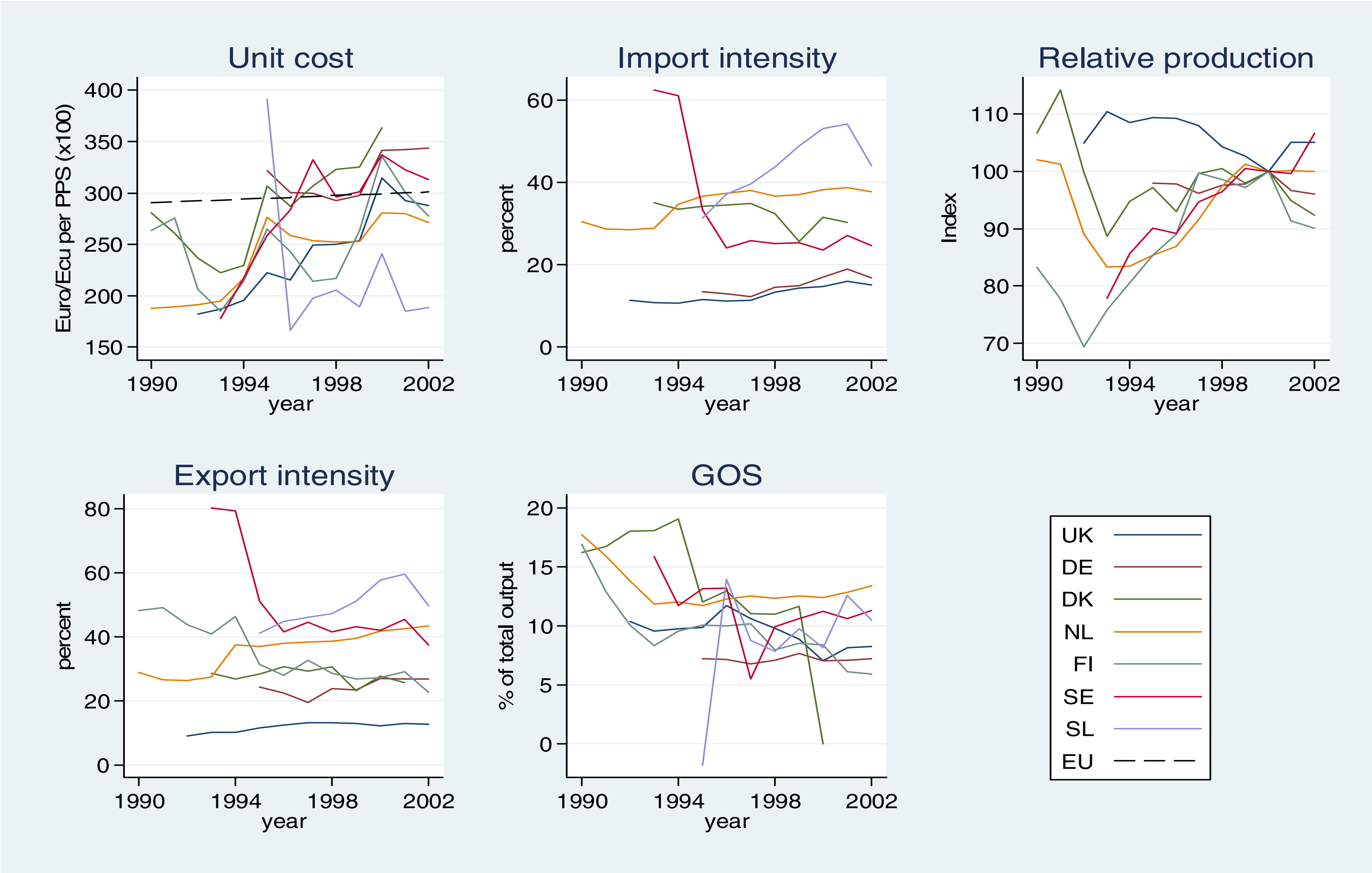

Figure 4.2 **Indicator series for NACE 21.2**

4.3 Basic chemicals (NACE 24.1)

Apart from unit costs where five of the seven countries exhibit a significant positive trend, the indicators in the basic chemicals sector show less movement over the study period than in the other sectors. Unit costs in Germany, the Netherlands, Finland, Sweden and the United Kingdom rose more quickly than the average for all EU15 countries. Relative production shows positive trends for Germany and Finland, with the former also having a positive trend for import intensity and the latter, a positive trend for export intensity. The only other statistically significant trend is for export intensity in the Netherlands.

Table 4.3 Summary of trends

Country	Relative Unit Cost	Import intensity	Relative Production	Export intensity	Overall
DE	+	+	+		
DK					
NL	+			-	
FI	+	n.a.	+	+	
SE	+				
SL			n.a.		
UK	+				

Note: No data available for import intensity for Finland, or for index of production for Slovenia

There is no evidence of changes in competitiveness in any of the seven countries. For Denmark and Slovenia, none of the available indicators showed any significant change over the study period. For the other five countries, there were insufficient consistent indicators to draw any conclusions.

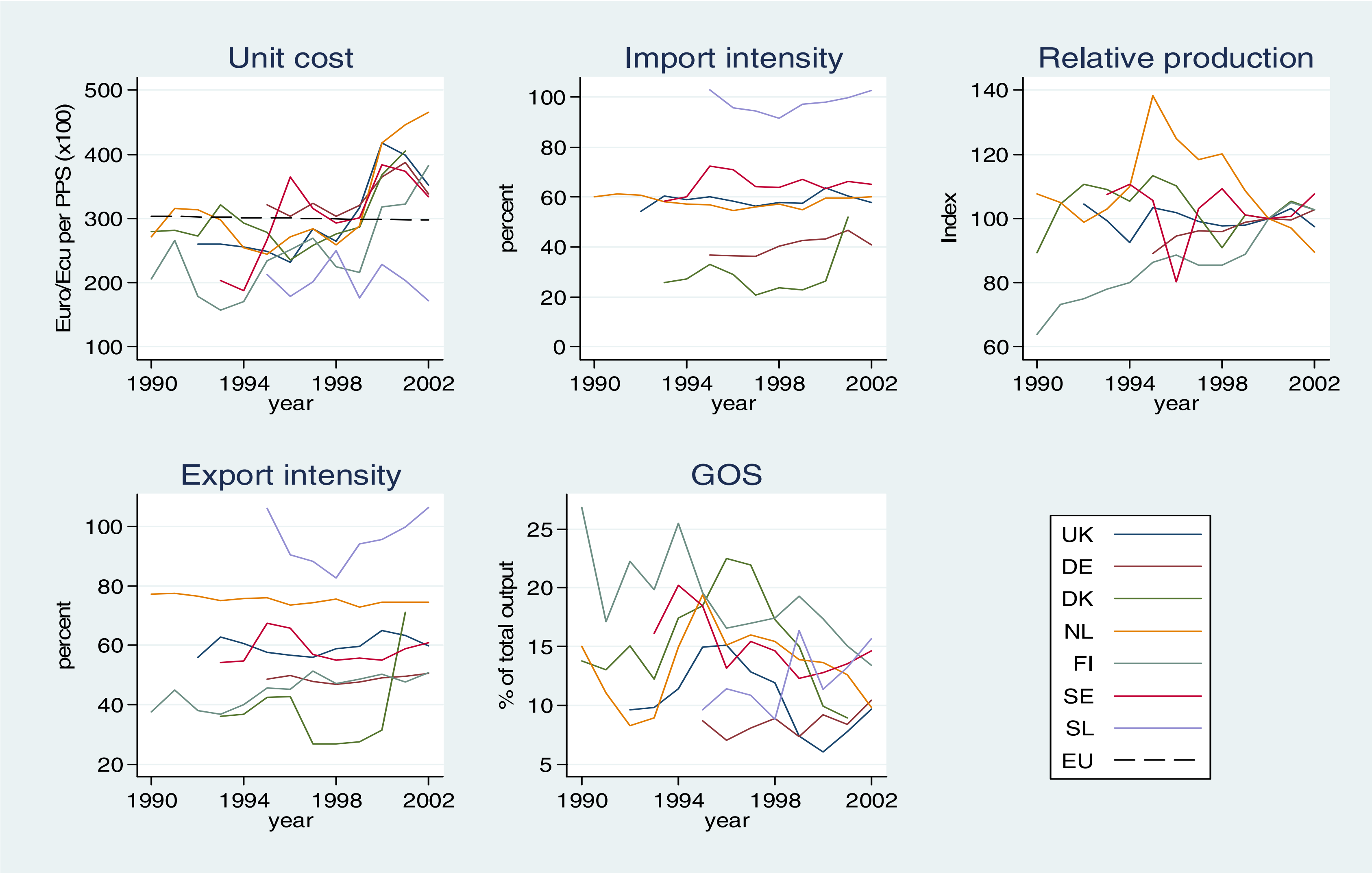

Figure 4.3 Indicator series for NACE 24.1

4.4 Pharmaceuticals (NACE 24.4)

In contrast to the basic chemicals sector, the indicators for the pharmaceuticals sector exhibit a large number of significant trends over the study period. Unit costs increased faster than the EU15 average for Germany, the Netherlands, Finland and the United Kingdom. Relative production increased for Denmark and Sweden, but declined in Germany, Finland and the Netherlands. With the exception of the Netherlands, import and export intensities follow parallel trends; with both indicators rising in Germany, Finland, Slovenia and the UK, and falling in Denmark and the Netherlands.

Table 4.4 Summary of trends

Country	Relative Unit Cost	Import intensity	Relative Production	Export intensity	Overall
DE	+	+	-	+	Loss
DK		-	+	-	Gain
NL	+	-	-	+	
FI	+	+	-	+	Loss
SE			+		
SL		+	n.a.	+	
UK	+	+		+	

Note: No data available for index of production for Slovenia

The indicators suggest that Germany and the United Kingdom suffered a deterioration of competitiveness between 1990 and 2002, but that there was an improvement for Denmark. It should be noted that because of the high export intensity for Denmark, the decline in this indicator is taken to imply an improvement in competitiveness. For the other four countries, there were insufficient consistent indicators to draw any conclusions.

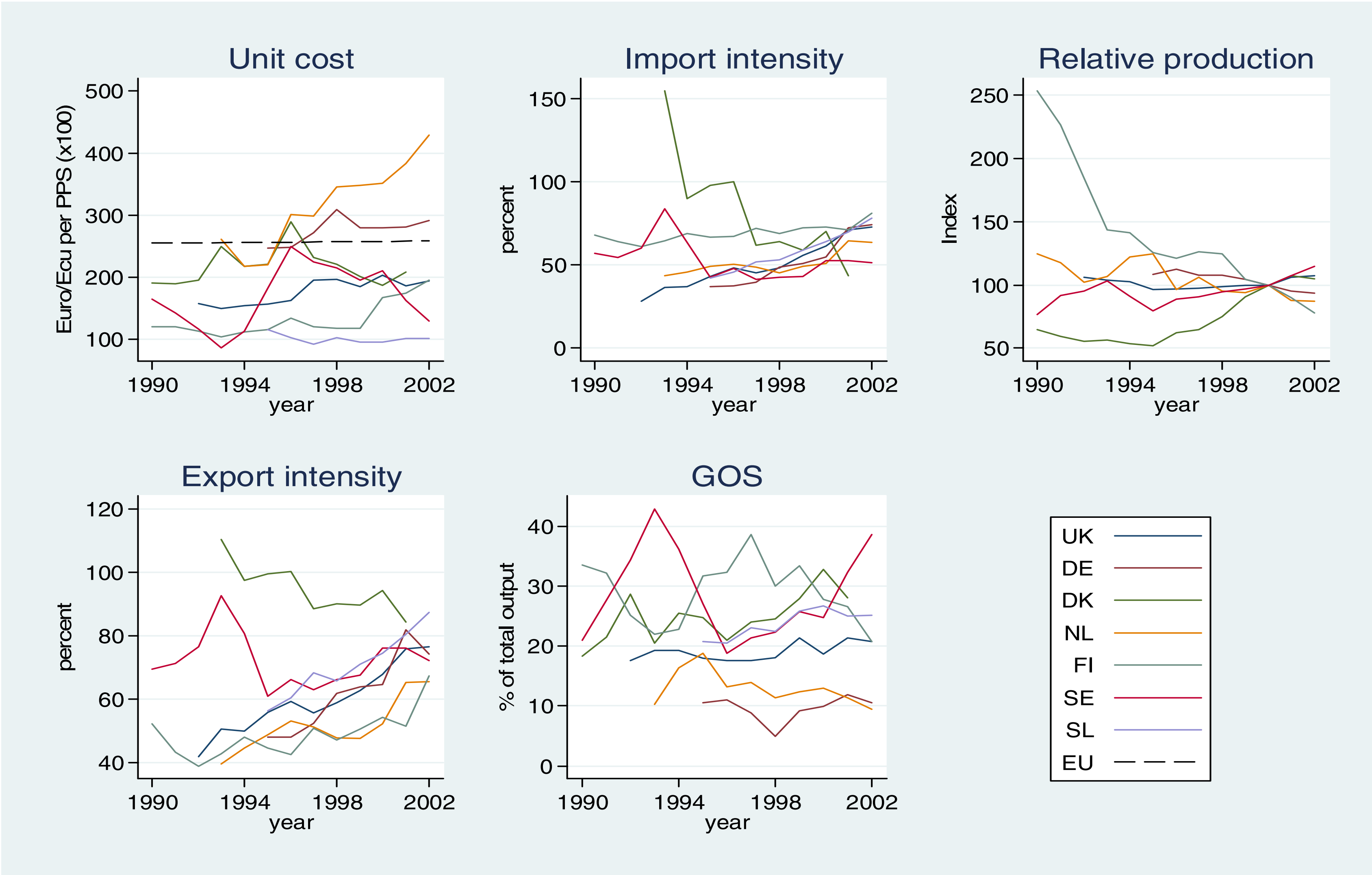

Figure 4.4 Indicator series for NACE 24.4

4.5 Glass and glass products (NACE 26.1)

Relative unit costs in the glass products sector exhibit a significant upward trend relative to the EU15 average trend in all seven countries. However, the picture for the other three indicators is much less consistent. Import and export intensity are both decreasing over the study period for Sweden and Slovenia and increasing in Germany and Denmark. Relative production declined for Germany and Sweden but increased for the Netherlands.

Table 4.5 Summary of trends

Country	Relative Unit Cost	Import intensity	Relative Production	Export intensity	Overall
DE	+	+	-	+	Loss
DK	+	+		+	
NL	+	n.a.	+	n.a.	
FI	+	n.a.			
SE	+	-	-	-	
SL	+	-	n.a.	-	
UK	+				

Note: No data available for import intensity for Finland or the Netherlands, for export intensity for the Netherlands, or for index of production for Slovenia

The indicators suggest that competitiveness deteriorated between 1990 and 2002 for Germany, where an increase in relative unit cost is supported by a declining relative production index and increasing import penetration. For the other six countries, there are insufficient consistent indicators to make any inferences about changes in competitiveness.

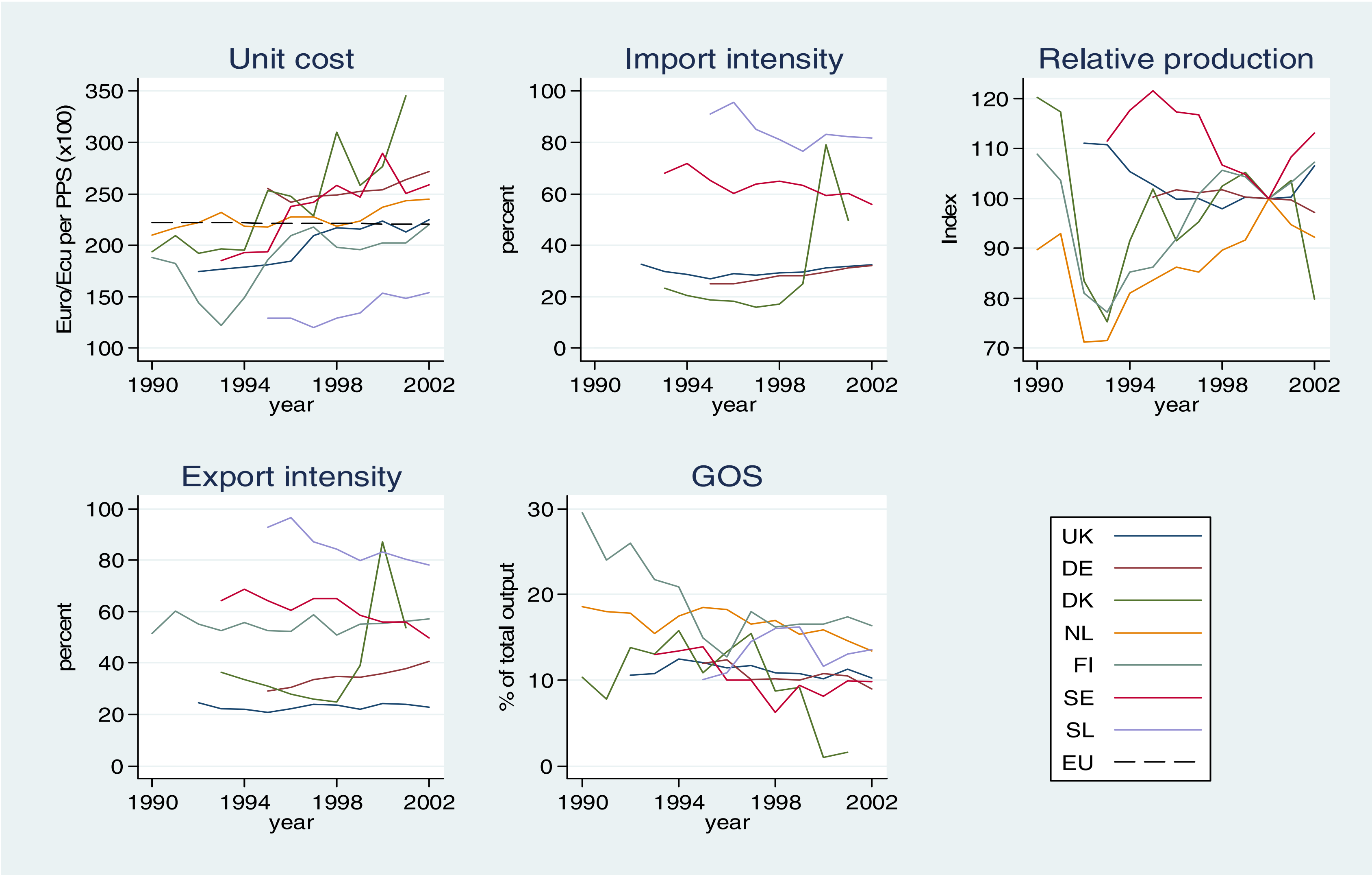

Figure 4.5 Indicator series for NACE 26.1

4.6 Cement, lime and plaster (NACE 26.5)

In the cement sector relative unit costs are increasing over the study period for Denmark, the Netherlands, Sweden and the United Kingdom, with no discernable trends in the other three countries. Again, the other three indicators provide a mixed picture, increasing in some countries and declining in others. Import intensity declined for Germany and Denmark, but increased for Slovenia and the United Kingdom. While export intensity exhibits an upward trend for Germany and Finland, it declined for Denmark. Relative production is volatile in all countries except Germany (which exhibits a negative trend) and Denmark (which exhibits a positive trend).

Table 4.6 Summary of trends

Country	Relative Unit Cost	Import intensity	Relative Production	Export intensity	Overall
DE		-	-	+	
DK	+	-	+	-	
NL	+	n.a.		n.a.	
FI		n.a.		+	
SE	+				
SL		+	n.a.		
UK	+	+			

Note: No data available for import intensity for Finland or the Netherlands, for export intensity for the Netherlands, or for index of production for Slovenia

There is no evidence of changes in competitiveness in any of the seven countries. While all seven countries have significant trends for at least one of the indicators, there is insufficient consistency between the trends to draw any conclusions.

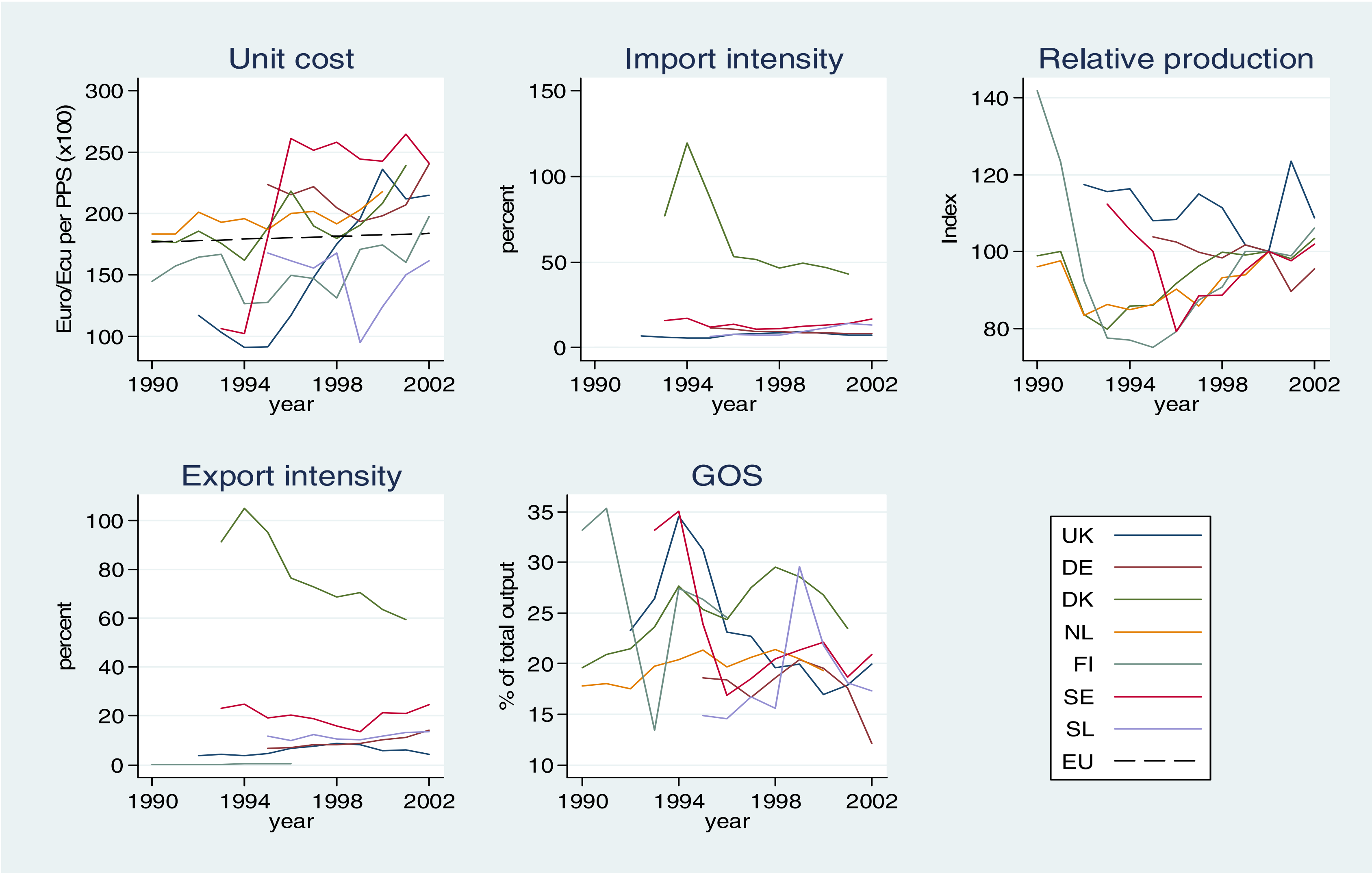

Figure 4.6 Indicator series for NACE 26.5

4.7 Ferrous metals (NACE 27.1-3)

In the ferrous metal sector all but two of the countries exhibit a significant positive trend in unit costs relative to the EU15 average trend. Import intensity is rising significantly in Germany, Sweden and the UK. The indicator shows no clear trend in Slovenia or the Netherlands, but both countries are outliers with import intensities that are on average twice/three times higher than in the remaining countries. The situation is similar for export intensity. There is a positive trend in Germany, Sweden and the UK, but no clear trend in the Netherlands where export intensity is more than twice as high. Relative production in ferrous metals is increasing Finland and Sweden, falling in the UK and fairly stable in the remaining countries.

Table 4.7 Summary of trends

Country	Relative Unit Cost	Import intensity	Relative Production	Export intensity	Overall
DE		+		+	
DK	+				
NL	+				
FI	+		+		
SE	+	+	+	+	
SL	-		n.a.	+	
UK	+	+	-		Loss

Note: No data available for index of production for Slovenia

The UK is the only country where indicator movements suggest that there was a loss of competitiveness. For the other six countries, there is insufficient consistency between the trends to draw any conclusions.

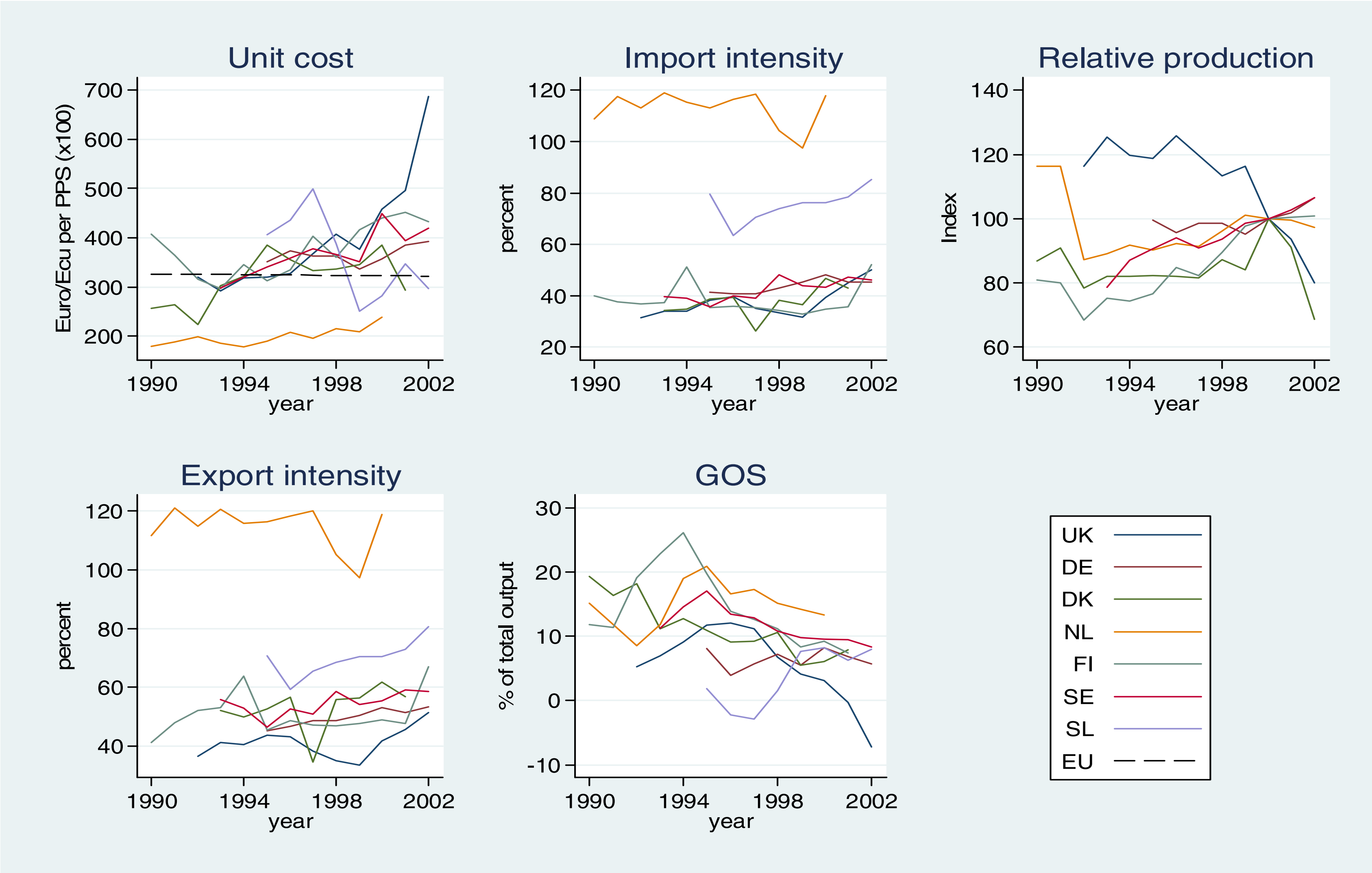

Figure 4.7 Indicator series for NACE 27.1-3

4.8 Non-ferrous metals (NACE 27.4)

The non-ferrous metals sector does not follow the pattern of mostly rising relative unit costs across countries that are seen in the other sectors (apart from 15.1). Only in Denmark, the Netherlands and the United Kingdom do unit costs rise faster than the EU15 average. In Slovenia they are falling and they are rather volatile in the remaining countries, especially Finland. Import and export intensities are generally stable or increasing slightly over the study period. The two exceptions are Slovenia, where both indicators rise and fall again around 1998, and Finland, where the export intensity declines over the first five years before picking up again. Relative production increases on average over the study period for Germany, Finland and Sweden, but falls for the United Kingdom.

Table 4.8 Summary of trends

Country	Relative Unit Cost	Import intensity	Relative Production	Export intensity	Overall
DE			+	+	
DK	+				
NL	+	+		+	Loss
FI			+	-	
SE		+	+	+	
SL	-		n.a.		
UK	+	+	-	+	Loss

Note: No data available for index of production for Slovenia

The indicators suggest that competitiveness deteriorated between 1990 and 2002 for the Netherlands and for the United Kingdom; with rising unit costs and import intensity being supported by rising export intensity in the Netherlands (NB: export intensity is greater than 100%) and declining relative production in the United Kingdom. For the other five countries, there are insufficient consistent indicators to make any inferences about changes in competitiveness.

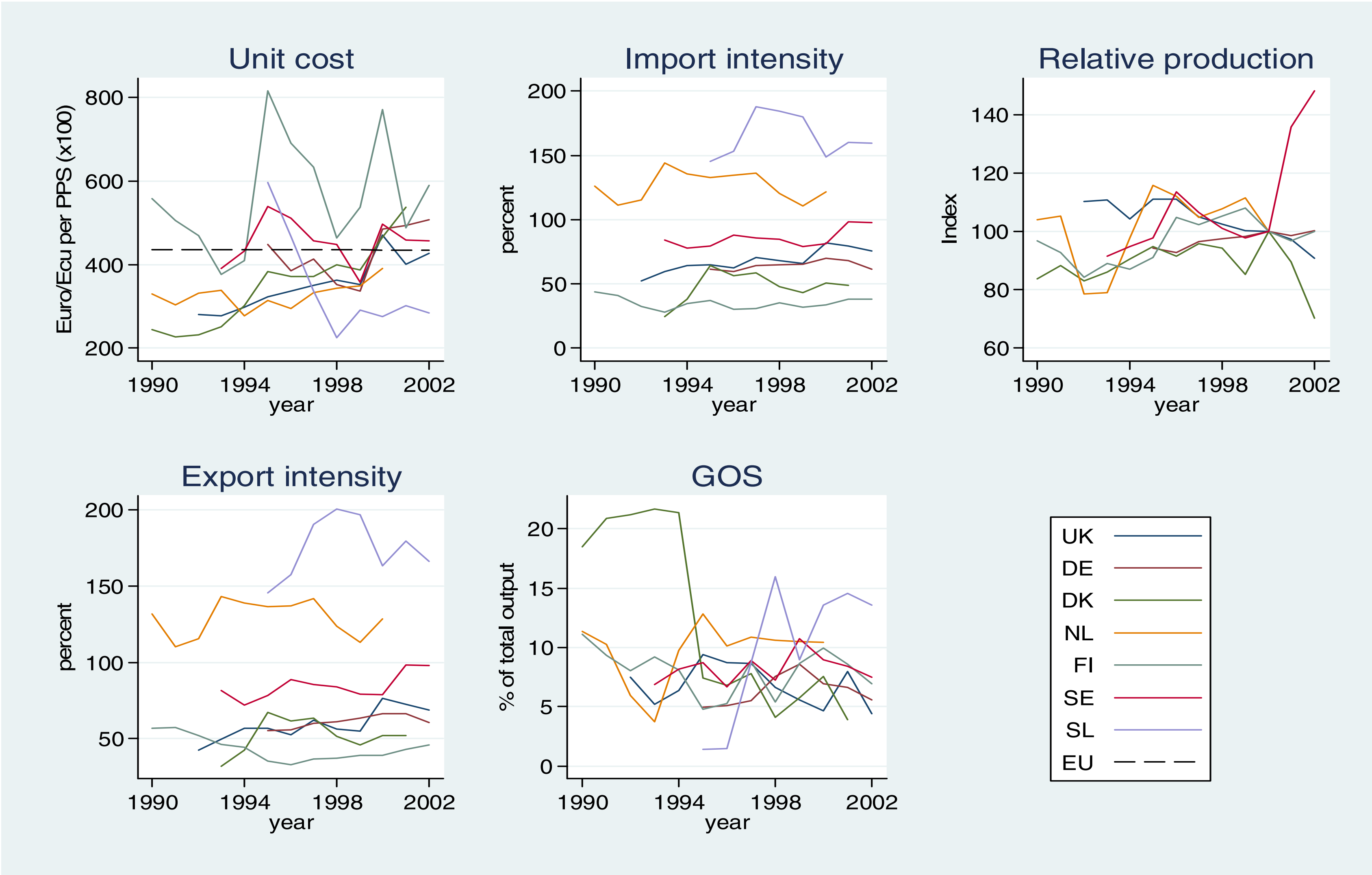

Figure 4.8 **Indicator series for NACE 27.4**

4.9 Summary

In this section the trends in the selected indicators between 1990 and 2002 have been reviewed for each of the eight selected sectors to see whether there is any evidence that competitiveness deteriorated for any of the ETR countries over this period. The main findings of this review are that:

- In forty-five of the fifty-six cases considered (i.e. 80%), there is no consistent evidence that there were any changes in competitiveness between 1990 and 2002.
- In only nine cases (16%), do the trends in the indicators suggest there was a loss of competitiveness over this period. Four of these cases relate to the United Kingdom, three to Germany, and one each to Finland and the Netherlands.
- In two cases (4%), the trends in the indicators suggest that there was actually an improvement in competitiveness. This was so for the meat products sector in the Netherlands and the pharmaceuticals sector in Denmark.

Thus, there is little evidence to suggest that the seven ETR countries suffered any widespread or significant loss of competitiveness over this period.

5. Conclusions

In this report the effects of environmental tax reform on competitiveness on selected industrial sectors in seven European countries which have implemented tax reforms over the period 1990-2002 has been assessed.

Trends in imputed carbon-energy tax rates and energy expenditures (as a percentage of total production costs) were analysed in Section 2. Given the magnitude of the resultant increases in average tax rates (mostly lower than 10%) and the relative insignificance of energy in total costs (only 7% on average), it would appear that the ETRs that were introduced in the seven case-study countries had little impact on unit production costs. The one possible exception to this is the cement, lime and plaster sector, where the resultant cost increases ranged up to 6%.

A theoretical model which forms the basis of the choice of competitiveness indicators is put forward. The competitiveness of a firm is defined to improve if the increase in its unit production cost is less than the average increase in unit production costs of all other firms, or if the reduction in its unit production cost is greater than average reduction of the other firms. Given the difficulty in obtaining reliable data on relative unit costs, four other competitiveness indicators are suggested as "proxy variables": gross operating surplus as a percentage of total output, import intensity, export intensity and relative production. Of these four indicators it is shown that only three can be deemed reliable indicators of changes in competitiveness: a decrease in competitiveness is reflected in an increase import intensity and relative production and a decrease in export intensity (under certain conditions).

In Section 4 relative unit costs and the four competitiveness indicators are analysed in detail for each of the selected countries and industrial sectors over the study period. The indicators were either directly available or constructed from the NACE 3 level multi-country dataset put together as part of the COMETR project. A general caveat is in order with regards to the quality of the data. In some cases missing or clearly aberrant values had to be interpolated.

Overall the data quality and the high degree of volatility in the data make it difficult to identify clear trends. Out of the fifty-six cases considered (i.e. seven countries by eight sectors) the data show no support for a change in competitiveness in forty-five cases. Only in nine cases do indicator movements point to a loss in competitiveness. These occur in the United Kingdom (sectors 15.1, 21.1, 27.1-3, 27.4), Germany (21.2, 24.4, 26.1), Finland (24.4) and the Netherlands (27.4). An increase in competitiveness is found for the Danish pharmaceuticals industry and for the meat processing industry in the Netherlands.

The two sides of the analysis are brought together in Table 5.1, in which the fifty-six cases are grouped according to the percentage change in unit production cost and the changes in competitiveness observed in the data. Note that because revenue recycling was not taken into account the changes in unit cost represent upper bounds.

Table 5.1 Breakdown of case-study countries / sectors

Impact of ETR on unit production costs	Change in competitiveness			Total
	Gain	No change	Loss	
Less than 1%	2	39	9	50
1%-5%	0	5	0	5
More than 5%	0	1	0	1
Total	2	45	9	56

Losses in competitiveness occur only in countries / sectors where the impact of the ETRs on unit costs has been smaller than (or equal to) one percent. There is no case of a decrease (or increase) in competitiveness where the impact of the ETRs was above 1%. In Slovenia (26.5) where the impact of the ETR was above 5% no change in competitiveness was registered in the data.

In conclusion, the ETRs have not been significant in terms of their impact on unit production costs (below 1% in 50 cases). While there is some evidence for a decline in competitiveness in selected countries / sectors, it is not possible to conclude that the reform was a significant contributing factor.

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Annex A: Derivation of analytical results

A1. Model definition

A homogeneous product is produced by firms based in <u>sectors</u> j = 1, … J and is purchased by consumers based in <u>markets</u> k = 1, … K; where both sectors and markets are defined geographically. In order to simplify the notation it is assumed that there is a single sector and a single market for each country in the world, although this does not have to be the case. Consequently the number of markets is equal to the number of sectors (i.e. J = K); with each sector having a "home market" and K-1 "export markets".

In all sectors, firms have constant unit costs of production (c_i^j) and a fixed cost (F_i^j), both of which are firm-specific. In addition, they incur market-specific constant unit transportation costs (r^{jk}) which are assumed to be the same for all firms in a particular sector. It is assumed that the transportation costs are equal to zero for all home-market sales. The firms compete as Cournot oligopolists in all markets, with the prices being determined by market-specific linear inverse demand functions: $P^k = a^k - b^k X^{\cdot k}$.

A2. Expressions for model variables

Under the assumption that all firms have strictly positive sales in all markets, the necessary and sufficient condition for firm $i \in I^j$ of sector $j \in J$ to maximize its profit in market $k \in K$ is:[29]

$$b^k x_i^{jk} = (a^k - c_i^j - r^{jk}) - b^k X^{\cdot k} \qquad \ldots \text{(A1)}$$

where:

a^k is the choke price for market $k \in K$

b^k is the slope of the inverse demand curve for market $k \in K$

c_i^j is the unit production cost if firm $i \in I^J$ in sector $j \in J$

r^{jk} is the common unit transportation cost of firms in sector $j \in J$ for market $k \in K$ (with $r^{jk} = 0$ if j = k)

Summing across all of the firms in sector $j \in J$ yields:

$$b^k X^{jk} = N^j \left[(a^k - c^j - r^{jk}) - b^k X^{\cdot k} \right] \qquad \ldots \text{(A2)}$$

where:

$$c^j = \frac{1}{N^j} \left(\sum_{i \in I^j} c_i^j \right)$$ is the average unit production cost of sector $j \in J$

[29] The assumption that all firms have strictly positive sales in all markets imposes an upper bound on the total number of firms. The magnitude of this upper bound is considered below.

Summing across all sectors and rearranging terms yields the following expression for total sales in market $k \in K$:

$$X^{\cdot k} = \left(\frac{N}{N+1} \right) \left(\frac{a^k - \hat{c} - r^k}{b^k} \right) \qquad \ldots \text{(A3)}$$

where

$$\hat{c} = \frac{1}{N} \left(\sum_{j \in J} \sum_{i \in I^j} c_i^j \right) = \frac{1}{N} \left(\sum_{j \in J} N^j c^j \right)$$ is the overall average unit production cost

$$r^k = \frac{1}{N} \left(\sum_{j \in J} N^j r^{jk} \right)$$ is the overall average unit transportation cost

The assumption that all firms have strictly positive sales in all markets imposes the following restrictions on the parameter values in the model:

$$a^k - (c_i^j + r^{jk}) > N (c_i^j + r^{jk}) - \sum_{j \in J} \sum_{i \in I^j} (c_i^j + r^{jk}) \qquad \text{for all } i \in I^j, j \in J, k \in K$$

Interpretation of these restrictions is facilitated if they are rearranged to yield[30]:

$$a^k - (\hat{c} + r^k) > (N+1) [(c_i^j + r^{jk}) - (\hat{c} + r^k)] \qquad \text{for all } i \in I^j, j \in J, k \in K$$

If sales in market $k \in K$ are positive (as is assumed to be the case) then the left-hand side is positive and hence the condition is satisfied for all values of N for any firm that has a lower unit cost of sales than the market average (i.e. $c_i^j + r^{jk} < \hat{c} + r^k$). Consequently, the restriction only comes into play when a firm has a unit cost of sales that exceeds the market average (i.e. the expression inside the square brackets on the right-hand side is positive). It follows that the upper bound for the total number of firms is given by:

$$N + 1 < \operatorname*{Min}_{i\,j\,k} \left(\frac{a^k - (\hat{c} + r^k)}{(c_i^j + r^{jk}) - (\hat{c} + r^k)} \right) \equiv \operatorname*{Min}_{i\,j\,k} \left(\frac{A^k}{B^{ijk}} \right) \qquad \ldots \text{(A4)}$$

The expression inside the parentheses on the right-hand side is illustrated in Figure A1 for a representative market. It can be seen from this that the value of the upper bound on the total number of firms will be large if all markets have high choke prices (relative to the average unit cost of sales) and there is little variation in the unit cost of sales between firms; and will be small if any of the markets have a relatively low choke price and significant variation in unit costs.

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[30] Strictly speaking $\hat{c}$ and r^k are summary parameters, not independent exogenous parameters for the model.

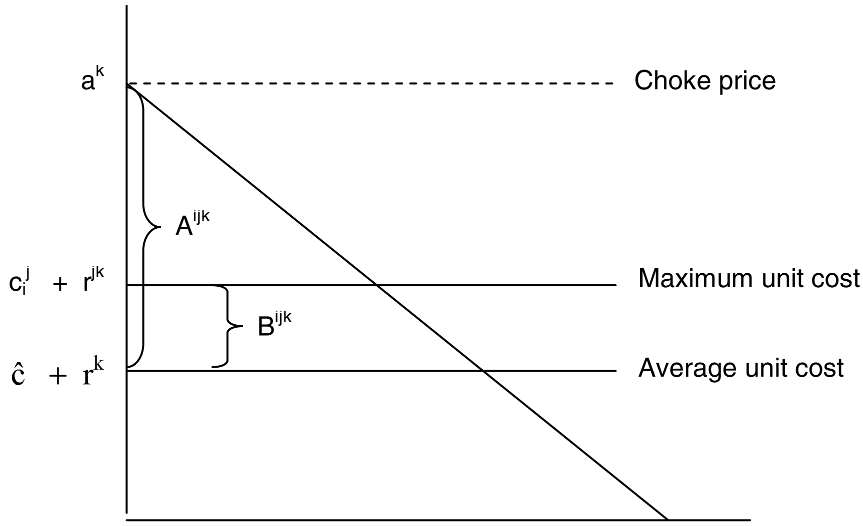

Figure A1: Representative market

It follows directly from the inverse demand function for market $k \in K$ that:

$$P^k = \left(\frac{a^k}{N+1} \right) + \left(\frac{N}{N+1} \right) (\hat{c} + r^k) \qquad \text{… (A4)}$$

Substituting (A3) back into (A2) and rearranging terms yields the following expression for the sales of sector $j \in J$ in market $k \in K$:

$$X^{jk} = \frac{1}{b^k} \left(\frac{N^j}{N+1} \right) \left(a^k - (N+1)(c^j + r^{jk}) + N(\hat{c} + r^k) \right) \qquad \text{… (A5)}$$

Rearranging conditions (A2) yields following expressions for the market share of sector $j \in J$ in market $k \in K$ and the sector' share of total sales / production in the equilibrium:

$$\sigma^{jk} \equiv N^j \left(\left(\frac{a^k - c^j - r^{jk}}{b^k X^{\cdot k}} \right) - 1 \right) \qquad \text{… (A6a)}$$

$$\sigma^{j\cdot} \equiv N^j \left(\sum_{k \in K} \left(\frac{a^k - c^j - r^{jk}}{b^k X} \right) - 1 \right) \qquad \text{… (A6b)}$$

where $X^{\cdot k}$ and X are the equilibrium values. In addition to the market shares, the following equilibrium identities for the import intensity and export intensity of sector $j \in J$; the profitability of sector $j \in J$ in market $k \in K$; and the overall profitability of sector $j \in J$ are used in the analysis:

$$\mu^j \equiv 1 - \sigma^{jj} \qquad \text{… (A7)}$$

$$\xi^{j} \equiv 1 - \left(\frac{X^{jj}}{X^{j\cdot}} \right) \quad \dots \text{(A8)}$$

$$\pi^{jk} \equiv 1 - \left(\frac{\breve{c}^{jk} + r^{jk}}{P^{k}} \right) \quad \dots \text{(A9)}$$

$$\pi^{j} \equiv \sum_{k \in K} \pi^{jk} \gamma^{jk} - \left(\frac{F^{j}}{R^{j\cdot}} \right) \quad \dots \text{(A10)}$$

where $\sigma^{jj} = \sigma^{jk=j}$ and $X^{jj} = X^{jk=j}$ are respectively the sector's market share and sales in its home market and

$\breve{c}^{jk} = \frac{1}{X^{jk}} \left(\sum_{i \in I^{j}} c_i^{j} x_i^{jk} \right)$ is the average production cost of sales of sector $j \in J$ in market $k \in K$

$\gamma^{jk} = \frac{R^{jk}}{R^{j\cdot}}$ is the share of market $k \in K$ of the total revenue of sector $j \in J$

A3. Comparative statics

It is assumed that all of the parameter values remain constant except the firms' unit production costs c_i^j ($i \in I^j$, $j \in J$) and the market choke prices a^k ($k \in K$). For small changes in these parameter values, the changes in the model variables are given by the total differentials of the respective expressions.

a) Average costs

$$d\hat{c} = \frac{1}{N} \left(\sum_{j \in J} \sum_{i \in I^{j}} d c_i^{j} \right) = \frac{1}{N} \left(\sum_{j \in J} N^{j} d c^{j} \right) \quad \dots \text{(A11a)}$$

$$dc^{j} = \frac{1}{N^{j}} \left(\sum_{i \in I^{j}} d c_i^{j} \right) \quad \dots \text{(A11b)}$$

$$d\breve{c}^{jk} = \frac{1}{X^{jk}} \left(\sum_{i \in I^{j}} d c_i^{j} x_i^{jk} + \sum_{i \in I^{j}} c_i^{j} d x_i^{jk} - d X^{jk} \breve{c}^{jk} \right) \quad \dots \text{(A11c)}$$

Under the assumption that the change in unit production costs is the same for all firms in a particular sector (i.e. $dc_i^j = dc^j$ for all $j \in J$) it follows directly from (A1) that $dx_i^{jk} = dX^{jk} / N^j$. Consequently, (A11c) simplifies to:

$$d\breve{c}^{jk} = dc^{j} + \frac{d X^{jk}}{X^{jk}} \left(c^{j} - \breve{c}^{jk} \right) \quad \dots \text{(A11d)}$$

b) Market demand and price

$$dX^{\cdot k} = \frac{1}{b^k}\left(\frac{N}{N+1}\right)(da^k - d\hat{c}) \quad \ldots \text{(A12a)}$$

$$dP^k = \left(\frac{1}{N+1}\right)da^k + \left(\frac{N}{N+1}\right)d\hat{c} \quad \ldots \text{(A12b)}$$

c) Sector sales

$$dX^{jk} = \frac{N^j}{b^k}\left(\left(\frac{1}{N+1}\right)da^k - dc^j + \left(\frac{N}{N+1}\right)d\hat{c}\right)$$

$$= \frac{N^j}{b^k}\left(\left(\frac{1}{N+1}\right)(da^k - d\hat{c}) - (dc^j - d\hat{c})\right) \quad \ldots \text{(A13)}$$

Therefore the necessary and sufficient conditions for sales of sector $j \in J$ in market $k \in K$ to increase are:

$$dc^j - d\hat{c} < \left(\frac{1}{N+1}\right)(da^k - d\hat{c}) \quad \ldots \text{(A14)}$$

d) Global production

$$dX = \sum_{k\in K} dX^{\cdot k}$$

$$= \left(\frac{N}{N+1}\right)\sum_{k\in K}\left(\frac{da^k - d\hat{c}}{b^k}\right) \quad \ldots \text{(A15)}$$

e) Sector production

$$dX^{j\cdot} = \sum_{k\in K} dX^{jk}$$

$$= \sum_{k\in K}\frac{N^j}{b^k}\left(\left(\frac{1}{N+1}\right)(da^k - d\hat{c}) - (dc^j - d\hat{c})\right) \quad \ldots \text{(A16)}$$

f) Share of global production

$$d\sigma^{j\cdot} = \left(\frac{N^j}{X^2}\right)\left[\sum_{k\in K}\left(\frac{da^k - dc^j}{b^k}\right)X - \sum_{k\in K}\left(\frac{a^k - c^j - r^{jk}}{b^k}\right)dX\right]$$

$$= \left(\frac{N^j}{X}\right)\left[\sum_{k\in K}\left(\frac{da^k - dc^j}{b^k}\right) - \left(1+\frac{\sigma^j}{N^j}\right)dX\right]$$

$$= \left(\frac{N^j}{X}\right)\left[\sum_{k\in K}\left(\frac{da^k - dc^j}{b^k}\right) - \left(1+\frac{\sigma^j}{N^j}\right)\left(\frac{N}{N+1}\right)\sum_{k\in K}\left(\frac{da^k - d\hat{c}}{b^k}\right)\right]$$

$$= \left(\frac{N^j}{X}\right)\left[(d\hat{a}^k - dc^j) - \left(1+\frac{\sigma^j}{N^j}\right)\left(\frac{N}{N+1}\right)(d\hat{a}^k - d\hat{c})\right]\sum_{k\in K}\left(\frac{1}{b^k}\right) \quad \text{(A17)}$$

where $d\hat{a} = \left(\sum_{k\in K}\frac{da^k}{b^k}\right)\Big/\left(\sum_{k\in K}\frac{1}{b^k}\right)$

It follows directly that the necessary condition and sufficient condition for share of global production of sector $j\in J$ to increase (decrease) is that the expression inside the square brackets is positive (negative). Rearranging terms yields the following condition:

$$dc^j - d\hat{c} \quad < (>) \quad \frac{1}{N+1}\left(1 - \frac{\sigma^{j\cdot}}{\rho^j}\right)(d\hat{a} - d\hat{c}) \qquad \ldots \text{(A18)}$$

where $\rho^j = \dfrac{N^j}{N}$ is the share of the total number of firms accounted for by sector $j\in J$

g) Import intensity

$$d\mu^j \equiv -d\sigma^{jj}$$

$$= -\left(\frac{N^j}{X^{\cdot j\,2}}\right)\left[\left(\frac{da^j - dc^j}{b^j}\right)X^{\cdot j} - \left(\frac{a^j - c^j}{b^j}\right)dX^{\cdot j}\right]$$

$$= -\left(\frac{N^j}{X^{\cdot j}}\right)\left[\left(\frac{da^j - dc^j}{b^j}\right) - \left(1+\frac{\sigma^{jj}}{N^j}\right)dX^{\cdot j}\right]$$

$$= -\left(\frac{N^j}{b^j X^{\cdot j}}\right)\left[(da^j - dc^j) - \left(1+\frac{\sigma^{jj}}{N^j}\right)\left(\frac{N}{N+1}\right)(da^j - d\hat{c})\right]$$

It follows directly that the necessary and sufficient condition for the import intensity of the home market for sector $j\in J$ to decrease (increase) is that the expression inside the square brackets is positive (negative). Rearranging terms yields the following condition:

$$dc^j - d\hat{c} \quad <(>) \quad \frac{1}{N+1}\left(1 - \frac{\sigma^{jj}}{\rho^j}\right)(da^j - d\hat{c}) \qquad \ldots \text{(A19)}$$

h) Export intensity

$$d\xi^j = \left(\frac{1}{X^{j\cdot}}\right)\left[\, dX^{jj} - (1-\xi^j)\, dX^{j\cdot} \,\right]$$

$$= \frac{N^j}{b^j X^{j\cdot}}\left(\left(\frac{1}{N+1}\right)(da^j - d\hat{c}) - (dc^j - d\hat{c})\right)$$

$$- \frac{(1-\xi^j)N^j}{X^{j\cdot}}\sum_{k\in K}\frac{1}{b^k}\left(\left(\frac{1}{N+1}\right)(da^k - d\hat{c}) - (dc^j - d\hat{c})\right)$$

$$= \frac{\eta^j N^j}{X^{j\cdot}}\left(\left(\frac{1}{N+1}\right)(da^j - d\hat{c}) - (dc^j - d\hat{c})\right)\left(\sum_{k\in K}\frac{1}{b^k}\right)$$

$$- \frac{(1-\xi^j)N^j}{X^{j\cdot}}\left(\left(\frac{1}{N+1}\right)(d\hat{a} - d\hat{c}) - (dc^j - d\hat{c})\right)\left(\sum_{k\in K}\frac{1}{b^k}\right)$$

$$= \left(\frac{(1-\nu^j)N^j}{X^{j\cdot}}\right)\left(\sum_{k\in K}\frac{1}{b^k}\right)\left[\,(d\hat{c} - dc^j) - \left(\frac{1}{N+1}\right)(d\hat{c} - d\tilde{a}^j)\,\right] \qquad \ldots \text{(A20)}$$

where
$$\eta^j = \frac{1}{K}\left(\frac{1}{b^j}\bigg/\left(\sum_{k\in K}\frac{1}{b^k}\bigg/K\right)\right)$$

$$\nu^j = \eta^j + \xi^j$$

$$d\tilde{a}^j = [\,(1-\xi^j)\, d\hat{a} - \eta^j da^j\,] / (1-\nu^j)$$

The value of the parameter η^j may be larger or smaller than one, depending on the values of its two components. Consequently, the necessary and sufficient condition for the export intensity of sector $j \in J$ to increase (decrease) is that the expression inside the square brackets is positive (negative) if $\eta^j < 1$, and negative (positive) if $\eta^j > 1$. That is:

$$dc^j - d\hat{c} \begin{cases} <(>) \quad \left(\frac{1}{N+1}\right)(d\tilde{a}^A - d\hat{c}) \quad \text{if} \quad \nu^j < 1 & \ldots \text{(A21a)} \\[2ex] >(<) \quad \left(\frac{1}{N+1}\right)(d\tilde{a}^A - d\hat{c}) \quad \text{if} \quad \nu^j > 1 & \ldots \text{(A21b)} \end{cases}$$

i) Profitability

$$d\pi^j \equiv d\pi_P^j + d\pi_M^j + d\pi_F^j$$

where $d\pi_P^j = \sum_{k\in K} d\pi^{jk}\gamma^{jk}$ (market profitability effect)

$$d\pi_M^j = \sum_{k\in K} \pi^{jk}\, d\gamma^{jk} \qquad \text{(revenue mix effect)}$$

$$d\pi_F^j = \frac{1}{R^{j\cdot}}\left(\frac{F^j}{R^{j\cdot}}\right) dR^{j\cdot} \qquad \text{(fixed cost effect)}$$

Market profitability effect

$$d\pi^{jk} = \frac{1}{P^k}\left[(1-\pi^{jk})\,dP^k - d\breve{c}^{jk}\right]$$

$$= \frac{(1-\pi^k)}{P^k}\left[\left(\frac{1}{N+1}\right)da^k + \left(\frac{N}{N+1}\right)d\hat{c}\right]$$

$$- \frac{1}{P^k}\left[dc^j + \frac{dX^{jk}}{X^{jk}}\left(c^j - \breve{c}^{jk}\right)\right]$$

$$= \frac{(1-\pi^{jk})}{P^k}\left[\left(\frac{1}{N+1}\right)(da^k - d\hat{c}) - (dc^j - d\hat{c}) - \Lambda^{jk}\right] \qquad \text{… (A22)}$$

where $\Lambda^{jk} = \left(\frac{\pi^{jk}}{1-\pi^{jk}}\right)dc^j + \left(\frac{1}{1-\pi^{jk}}\right)(c^j - \breve{c}^{jk})\frac{dX^{jk}}{X^{jk}}$

It follows directly that the necessary and sufficient condition for the profitability of sector $j\in J$ in market $k\in K$ to increase (decrease) is that the expression inside the square brackets is positive (negative). That is:

$$dc^j - d\hat{c} \;<(>)\; \left(\frac{1}{N+1}\right)(da^k - d\hat{c}) - \Lambda^{jk} \qquad \text{… (A23)}$$

Revenue mix effect

$$d\pi_M^j = \sum_{k\in K} \pi^{jk}\, d\gamma^{jk}$$

$$= \sum_{k\in K} (\pi^{jk} - \pi^{j\cdot}) \, d\gamma^{jk} \qquad \text{since} \qquad \sum_{k\in K} d\gamma^{jk} = 0$$

$$= \sum_{k\in K} \left(\frac{dR^{jk}}{R^{jk}} - \frac{dR^{j\cdot}}{R^{j\cdot}} \right) \varphi^{jk} \qquad \text{… (A24)}$$

where $\varphi^{jk} = \gamma^{jk} (\pi^{jk} - \pi^{j\cdot})$

Fixed cost effect

$$d\pi_F^{\,j} = \frac{1}{R^{j\cdot}} \left(\frac{F^j}{R^{j\cdot}} \right) \left(\sum_{k\in K} dR^{jk} \right)$$

$$= \frac{1}{R^{j\cdot}} \left(\frac{F^j}{R^{j\cdot}} \right) \left(\sum_{k\in K} \left[X^{jk} dP^k + P^k dX^{jk} \right] \right)$$

$$= \frac{1}{R^{j\cdot}} \left(\frac{F^j}{R^{j\cdot}} \right) \left[\sum_{k\in K} X^{jk} dP^k \left(1 + \frac{P^k}{X^{jk}} \frac{dX^{jk}}{dP^k} \right) \right]$$

But it follows from (A2) and the inverse demand curve that

$$\frac{P^k}{X^{jk}} \frac{dX^{jk}}{dP^k} = \left(\frac{P^k}{P^k - c^{jk} - r^{jk}} \right) \left(1 - \frac{dc^j}{dP^k} \right)$$

Therefore

$$d\pi_F^{\,j} = \frac{1}{R^{j\cdot}} \left(\frac{F^j}{R^{j\cdot}} \right) \left[\sum_{k\in K} X^{jk} dP^k \left(1 + \left(\frac{P^k}{P^k - c^{jk} - r^{jk}} \right) \left(1 - \frac{dc^j}{dP^k} \right) \right) \right] \qquad \text{… (A25)}$$

In the special case where there are no changes to the values of the choke prices in any of the markets (i.e. $da^k = 0$ for all $k\in K$), this can be simplified to give:

$$d\pi_F^{\,j} = \frac{d\hat{c}}{R^{j\cdot}} \left(\frac{F^j}{R^{j\cdot}} \right) \left(\frac{N}{N+1} \right) \left[\sum_{k\in K} X^{jk} \left(1 + \theta^{jk} \left(1 - \left(\frac{N+1}{N} \right) \frac{dc^j}{d\hat{c}} \right) \right) \right] \qquad \text{… (A26)}$$

where $$\theta^{jk} = \frac{P^k}{P^k - c^{jk} - r^{jk}} > 1$$

If $d\hat{c} > 0$, a sufficient condition for the fixed cost effect to be positive (i.e. $d\pi_F^{\,j} > 0$) for sector $j\in J$ is that:

$$dc^j - d\,\hat{c} \quad < \quad -\left(\frac{1}{N+1}\right) d\,\hat{c} \qquad \text{… (A27a)}$$

If $d\hat{c} < 0$, a sufficient condition for the fixed cost effect to be negative (i.e. $d\pi_F^j < 0$) for sector $j \in J$ is that:

$$dc^j - d\,\hat{c} \quad > \quad -\left(\frac{1}{N+1}\right) d\,\hat{c} \qquad \text{… (A27b)}$$

Annex B: Relationship between global market share and relative production index

Relative to a subset of sectors $M \subset J$, the relative index of production for sector $j \in M$ is equal to its index of production (relative to a given base year value) divided by the weighted average of the production indices for all of the sectors in the subset (all calculated using the same base year), where the weights reflect the relative market shares in the base year. That is:

$$\lambda^{j} = \left(\frac{X^{j\cdot}/\overline{X}^{j\cdot}}{\sum_{m\in M} (X^{m\cdot}/\overline{X}^{m\cdot})\, \varphi^{m\cdot}} \right) \qquad \text{… (B1)}$$

where $\varphi^{m\cdot}$ r= $\dfrac{\overline{X}^{m\cdot}}{\sum_{m\in M} \overline{X}^{m\cdot}}$

The relationship between the relative index of production for sector $j \in M \subset J$ and its share of global production ($\sigma^{j\cdot}$) is given by:

$$\sigma^{j\cdot} = \left(\frac{X^{j\cdot}}{\sum_{m\in M} X^{m\cdot}} \right) \left(\frac{\sum_{m\in M} X^{m\cdot}}{\sum_{m\in J} X^{m\cdot}} \right)$$

$$= \left(\frac{X^{j\cdot}/\overline{X}^{j\cdot}}{\sum_{m\in M} (X^{m\cdot}/\overline{X}^{m\cdot})\, \varphi^{m\cdot}} \right) \left(\frac{\sum_{m\in M} (X^{m\cdot}/\overline{X}^{m\cdot})\, \varphi^{m\cdot}}{\sum_{m\in J} (X^{m\cdot}/\overline{X}^{m\cdot})\, \varphi^{m\cdot}} \right) \left(\frac{\overline{X}^{j\cdot}}{\sum_{m\in J} \overline{X}^{m\cdot}} \right)$$

$$= \lambda^{j} \times \lambda^{M} \times \overline{\sigma}^{j\cdot} \qquad \text{… (B2)}$$

If the value of λ^{M} is constant (i.e. there is no change in the ratio of the weighted average of the production indices for the subset to the weighted average for all producers), then changes in global market share ($d\sigma^{j\cdot}$) are directly proportional to changes in the relative production index ($d\lambda^{j}$). The qualifying condition is more likely to be satisfied the greater the combined market share of the producers included in the subset.

The potential for cost-efficient improvements in industrial energy efficiency

WP3

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Section 1: Introduction

It is often claimed that there are significant opportunities for industry to improve energy efficiency at zero, or even negative, net cost. If this is the case, then the potential negative impacts on competitiveness of environmental tax reforms (ETRs) that increase industrial energy costs can be ameliorated by improvements in energy efficiency. The objective of this report is to see whether there is any evidence to support this claim for the eight COMETR sectors and if so, to assess the scale of the potential cost-efficient improvements in each case, using the United Kingdom as a case-study.[1, 2]

The issue is addressed using three different – but complementary approaches:

- A "bottom-up", technology-based simulation model (ENUSIM) is used to assess the potential for cost-efficient reductions in specific energy consumption (SEC) based on information about the costs and impacts of identified technologies, plus assumptions about economic parameters (such as energy prices, discount rate, etc.) and behavioural responses.
- Actual performance data reported under the relevant Climate Change Agreements (CCAs) is compared with "business-as-usual" counterfactuals (generated by ENUSIM) to assess the scale of the improvements in SEC that have been achieved over recent years. A comparison of the resultant reductions in energy costs with plausible estimates of energy-related capital expenditure allows likely payback periods to be assessed.
- A theoretical model is used to explore how a cost-minimizing firm might be expected to behave – with and without regulation, and to determine what information can be gleaned about the cost-efficiency of actual and target energy efficiency improvements from observed SEC performance data and the firm's use of the flexibility mechanisms allowed under the CCAs (i.e. the banking of over-performance for use in future periods and the trading of performance credits through the UKETS).

The different approaches are considered in turn in the next three sections; while the final section of the report pulls together their respective insights in order to draw some overall conclusions.

[1] Lack of disaggregated data means that it has only been possible to assess the potential for the Chemicals sector as a whole (i.e. NACE 24), rather than for Basic Chemicals (24.1) and Pharmaceuticals (24.4)

[2] This report is one of four emanating from the analyses of the sectors undertaken in Work-package 3. The other reports provide: a) an assessment of the Porter hypothesis in relation to energy efficiency; b) an econometric evaluation of the impact of energy taxes on competitiveness, output and exports; c) an assessment of the impacts of environmental tax reforms on the competitiveness of selected industrial sectors. Underlying the analyses is a series of country-datasets; with each dataset containing generic data such as exchange rates and emission factors, and sector-specific data on energy use, energy prices and taxes, economic variables and labour market variables.

Section 2: Ex ante modelling of potential

In this first section, the potential for cost-efficient improvements in energy efficiency in the five COMETR industrial sectors (i.e. NACE-level 2) is assessed by considering *ex ante* outputs from the ENUSIM (Industrial Energy End-Use Simulation Model)[3]. There are two ways in which the model allows the potential to be assessed. First, ENUSM includes a module that generates cost curves for each sector, which provide a direct indication of the potential scale of cost efficient (i.e. negative cost) improvements. However, these cost curves have a number of limitations. In particular, because of the way they are constructed they provide no indication of the time that may be required for the potential improvements to be achieved, or indeed whether they will ever be achieved. An alternative approach is to assess the potential over a specified time horizon by comparing the projections for specific energy consumption (SEC) produced by the model under two alternative scenarios – "business-as-usual" (BAU) and "all-cost-effective" (ACE). Both approaches are considered below. Following a brief overview of the ENUSIM model, the cost-curves produced by the module are reviewed and their limitations discussed. The potential cost-efficient improvements implied by these cost curves are then compared with estimates derived by comparing BAU and ACE projections over the ten-year period 2000 to 2010.

2.1 Overview of the ENUSIM model

ENUSIM is a "bottom up", technology-based, simulation model that generates projections for changes in SEC for industry sectors and sub-sectors, by modelling the uptake of energy efficiency measures. In doing so, it takes account of both economic and behavioural factors that affect the rate of investment in new technology. The endogenously calculated SEC projections are combined with exogenous assumptions about changes in activity levels (expressed in terms of an index of "useful energy demand" versus the base year) to generate projections for sectoral energy use and CO_2 emissions.

In ENUSIM, industry is disaggregated into sectors, sub-sectors (of which there are 110), devices and device technologies. The simulation is performed at the device level in this hierarchy; with technologies being applied or retrofitted to devices in various combinations in order to save energy. The resultant reductions in energy consumption for the individual devices are then aggregated to provide projections of changes in SEC at the sub-sector and sector level. The choice of technologies to be applied to a particular device is determined by a series of net present value (cost-efficiency) calculations; with technologies only being selected if they have a positive NPV (i.e. they are cost-efficient) and the order of their application depending on the relative magnitudes of their respective NPVs at an exogenously specified "normal" level of throughput. The extent to which each of the selected technologies is applied is determined by an "industry penetration index" (represented by a logistic S-curve). The shape of this curve for a particular technology – and hence the speed and extent

[3] ENUSIM was developed in the 1990s by the (then) Energy Technology Support Unit (ETSU) for the Global Atmosphere Division of the (then) Department of the Environment, Transport and the Regions (DETR), to support the projection of industrial carbon dioxide emissions. Since then it has been subject to a number of updates and enhancements; while responsibility for maintaining and developing the model has been transferred to new contractors. However, the basic structure and approach of the model have remained unchanged. Details of the model are provided in the ENUSIM Manual (DEFRA, 2002), produced by the current contractors, Entec UK Limited and Cambridge Econometrics.

to which it is taken up – depends partly on its endogenously-calculated cost-efficiency and partly on exogenous model parameters that reflect different "behavioural scenarios" (see below).

In addition to information about the costs and impacts of the individual technologies, the simulations are driven by exogenous assumptions regarding fuel prices, throughput levels (at the sub-sector level) and the discount rate to be used in the NPV calculations, and by the choice of a particular "behavioural scenario". There are three alternative scenarios which can be selected for any given model run:

- *Business-as-usual* (BAU): under which there is a continuation of recent trends, with industry continuing to take up energy-efficient technologies and energy-management procedures in the same way that it has in the past.
- *All-cost-effective* (ACE): under which all available cost-efficient energy-efficiency measures are adopted, but with the speed of adoption reflecting normal plant replacement cycles.
- *All-technically-possible* (ATP): under which the most energy efficient technologies available are adopted immediately, regardless of their cost-effectiveness.

However, in practice the ATP scenario is rarely used; with interest usually being focused on the BAU or ACE scenarios, or on the difference between them.

The scenarios are implemented in the model by two exogenous parameters that determine the shape of the penetration index curve in the base year for each technology.[4] The first parameter is the maximum final penetration for the technology; the second is the time taken to reach 50% penetration. In particular, the maximum penetration level is varied between scenarios; generally being set at very low levels under the BAU scenario and at much higher levels under the ACE scenario. Thus the choice of behavioural scenario has no impact on whether a particular technology is selected (i.e. whether it is cost-efficient) – this is determined by the other input parameters. It only affects the extent to which it is adopted in a particular year (i.e. its penetration).

Before moving on to consider some of the outputs from the simulations, it is important to emphasise the nature and limitations of the ENUSIM model. It is not a forecasting model that is designed to predict future outcomes. Nor is it an optimization model that can be used to identify the optimal cost-minimizing combination of technologies. Rather, it is a simulation model that provides projections of outcomes on the basis of the defined model algorithms and the assumed parameter values. As such, the "validity" of the projections depends on the extent to which the algorithms reflect the actual decision-making processes of firms and whether the parameter values are realistic.

2.2 ENUSIM cost curves

After ENUSIM has been run to generate projections under a particular behavioural scenario and set of parameter values, an "off-model" cost curve function can be invoked. The aim of this module is to

[4] The values of these parameters my change endogenously as the simulation moves forward in time to reflect changes in the cost-effectiveness of the technologies. For example, the model includes an algorithm that reduces the time taken for a technology to achieve 50% penetration if its payback period declines compared to the base-year value.

provide an indication of the scope for economically feasible energy efficiency improvements, relative to the actual (modelled) situation under the model run in a particular year.[5]

In order to generate the cost curves, the module considers all available technologies for each device and orders these (in descending order) based on the absolute NPV of the annual financial savings that they generate at a standard throughput (i.e. as in the main model – see above). The technologies are then applied to the device in that order, up to their respective pre-defined maximum penetration values (i.e. one of the exogenous parameters that determine the shape of the industry penetration index). The actual energy reduction for each technology is then re-calculated taking account of its actual (modelled) penetration in that year and the reductions that have already been achieved by technologies implemented earlier in the sequence, as are the resulting financial benefits.[6] Once the "ex post" impacts and savings of all technologies have been recalculated, the full list of technologies (i.e. across all devices) is ordered (in ascending order) on the basis of specific annual cost (i.e. annual cost per unit of energy saved) to generate the cost curve. The x-axis for these cost curves represents the absolute energy saving (or absolute carbon saving) that can be achieved. However, because output is exogenous (and hence unaffected by the application of the technologies), the axis can be rescaled to represent the percentage change in SEC by dividing by the total sector energy consumption in that year.[7]

The point at which the cost curve crosses the x-axis represents the maximum potential cost-efficient improvement in energy efficiency that can be achieved, given the actual (i.e. modelled) penetrations of the technologies in the year in question under the selected behavioural scenario. In most cases this is the BAU scenario, but this does not necessarily have to be the case. However, there are some important caveats that should be noted about these potential improvements. First, there is no implication that they can be achieved in that particular year. Indeed, the way in which the curves are constructed provides no indication of how long it might take to achieve the improvements, or even if they will ever be achieved within the time horizon of the model. Second, they are dependent on the exogenous values that are set for the maximum industry penetrations of the technologies under the ACE scenario, which are chosen by the user. Increasing (decreasing) the values of these parameters will increase (decrease) the potential for cost-efficient improvements.

Another point to note is that because of the order in which the technologies are applied in the generation of the cost curves, they should not be interpreted as marginal cost curves in the normal sense. As noted above, in the generation of the curves, the technologies are applied in the (increasing) order of their respective absolute costs; those with the lowest cost (i.e. greatest saving) being applied first. In contrast, the construction of a marginal cost curve would require that the technologies are applied in the order of their respective specific costs.

---

[5] The module generates cost curves for three preset years (1995, 2010 and 2020). However, it is possible to generate curves for any year of the modelled time-horizon.

[6] Because the impacts of technologies on device SEC are multiplicative, the absolute energy savings generated by a particular technology will depend on the impacts of the other technologies that have already been applied. For example, if these have reduced SEC by 25%, the reductions generated by the incremental technology will only be 75% of the those that it would generate if it was implemented on its own.

[7] Note that $\Delta E = Y \times (SEC_0 - SEC_1) = Y \times SEC_0 \times (1 - SEC_1 / SEC_0) = E_0 \times (1 - SEC_1 / SEC_0)$.

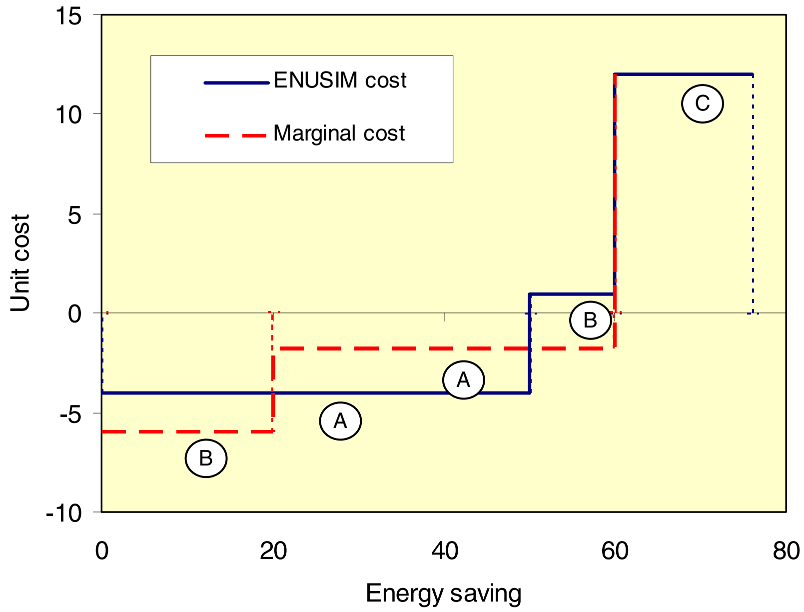

Figure 2.1 ENUSIM cost curves

The difference between the two approaches is illustrated by the simple example in Figure 2.1. In this example there are three technologies: A, B and C. All three technologies are cost effective (i.e. have negative costs) when applied in isolation: Technology C has the lowest saving, both in absolute and specific terms; Technology A has the highest absolute saving; while Technology B has the highest specific saving. Under the cost function algorithm, Technology A is applied first. Because this has a large impact on SEC, the scale of the energy savings that can be achieved by each of the other two technologies is reduced to such an extent that they are no longer cost effective, and hence are not applied. Under a marginal cost algorithm, Technology B is applied first. In this case however the impact on SEC is relative small and hence Technology A is still cost effective, although Technology C is not. As can be seen, reversing the order in which the two technologies are applied both reduces the minimum specific cost (from -4 to -6) and increases the maximum potential cost efficient reduction (from 50 to 60). Of course, this reflects the (relatively extreme) parameters that have been chosen for this particular example and in practice the differences between the two curves may not be that great. It can also be argued that the approach used in the ENUSIM cost function more closely reflects the way that firms behave in reality.

Figure 2.2 shows ENUSIM generated cost curves for the five COMETR sectors (i.e. NACE level-2). The curves are for 1995 and have been derived directly from the cost curves generated as part of the assessment of the UK Climate Change Programme on industrial CO_2 emissions (DEFRA, 2003); with the sectors' respective total energy consumption (TEC) estimates in that year being used to rescale the x-axis so that it represents the percentage improvement in SEC[8,9].

In each case the curves exhibit the same basic shape, with three distinct segments:

- a short steep segment where the cost is negative;

[8] The cost curves were generated using the BAU behavioural scenario and a 25% discount rate.

[9] Estimated total energy consumption is provided in the COMETR dataset for the United Kingdom (Work-package 3, DL3.3)

- a long flat segment where the cost is zero, or marginally negative;
- a short steep segment were the cost is positive.

Thus while the curves show that there is significant potential for improving energy efficiency without incurring positive net costs in all five sectors, only a small proportion of these improvements generate significant financial savings. For the large majority of the potential improvements, the costs and benefits of implementing the technologies are balanced (or the benefits only marginally outweigh the costs) and hence firms would be indifferent from a financial perspective. This suggests that it is more appropriate to define the potential for cost-efficient improvements in terms of a range (i.e. the middle segment of the curve) rather than a unique value (i.e. the point at which the curve crosses the axis).

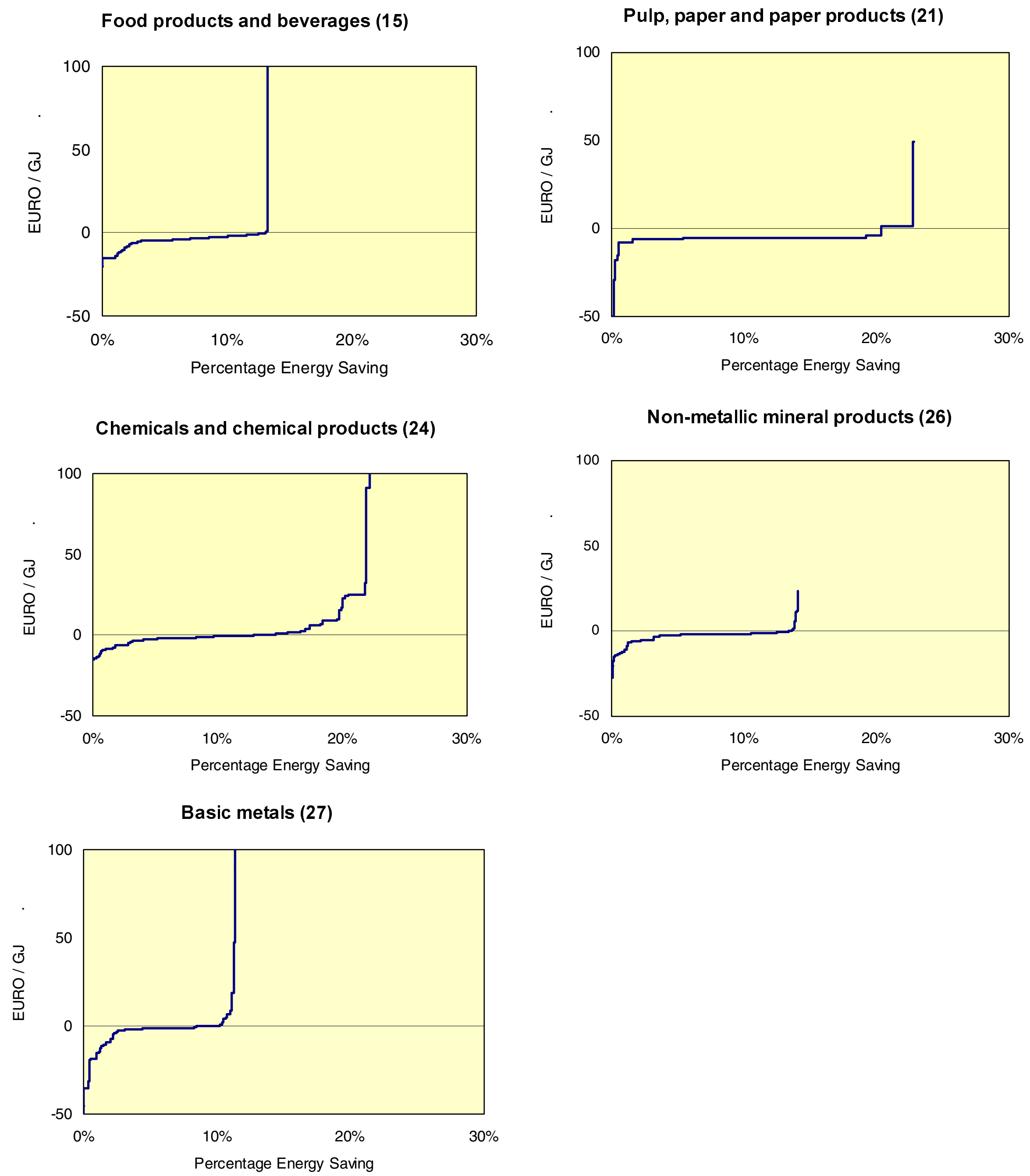

Figure 2.2 ENUSIM cost curves for COMETR sectors

Table 2.1 summarizes the ranges for cost-efficient improvements in energy efficiency for the five sectors. There is a great deal of consistency for the lower bound, with a minimum cost-efficient potential of around 3%-3.5% (apart from Pulp and Paper where it is only 1%). In contrast, the picture is much more varied for the upper bound, with the maximum potential ranging form 10.5% (for Basic Metals) to 23% (for Pulp and Paper).

Table 2.1: Potential for cost-efficient improvements in energy efficiency

Sector		Minimum	Maximum	Spread
15	Food products and beverages	3.5%	13.0%	9.5%
21	Pulp, paper and paper products	1.0%	23.0%	22.0%
24	Chemicals and chemical products	3.5%	17.0%	13.5%
26	Non-metallic mineral products	3.5%	14.0%	10.5%
27	Basic metals	3.0%	10.5%	7.5%

The large spread values in Table 2.1 suggest a high degree of uncertainty over the magnitudes of the improvements that one might expect to observe if firms were to manage their energy use cost-efficiently. However, it should be remembered that these curves reflect a specific set of input parameters and assumption – in particular an assumption of no significant changes in energy prices. If the energy prices were to be increased to reflect the introduction of the Climate Change Levy (or general increases in world energy prices) then the benefits of improving energy efficiency would increase. This would cause the curves to shift downwards, so that the flat middle segment would now be negative. In this case, the point-estimates provided by the upper bound values would provide a better indication of the improvements that could be expected.

2.3 SEC trajectory scenarios

As noted above, an alternative approach to assessing the potential for cost-efficient improvements in energy efficiency is to compare the ENUSIM projections for SEC under the BAU and ACE behavioural scenarios. The advantage of this approach is that it provides an indication of the potential improvement over a defined period of time, although this is of course dependent on the choice of model parameters – particularly those determining the shape of the penetration index curves. The approach is illustrated in Figure 2.3, where SEC in the base year (i.e. year 0) is equal to 100. By year T_2, the SEC value has fallen to X_2 under the BAU scenario; while under the ACE scenario it has fallen to Y_2.[10]. The potential cost efficient improvement over T_2 years (relative to year 0) is then given by:

$$\frac{X_2 - Y_2}{X_2} = 1 - \frac{Y_2}{X_2} = 1 - \frac{(Y_2/X_1)}{(X_2/X_1)}$$

Thus, the SEC values in year T_2 can either be measured relative to the actual (modelled) value in the base year, or relative to the BAU value (or an arbitrary value) in an intervening year T_1.

[10] For simplicity the SEC trajectories are shown as straight lines in Figure 2.3, but this is not necessary. Indeed, no information on the SEC values for the intervening years is required. In practice, the trajectories will be determined by the shapes of the penetration index curves and other model parameters.

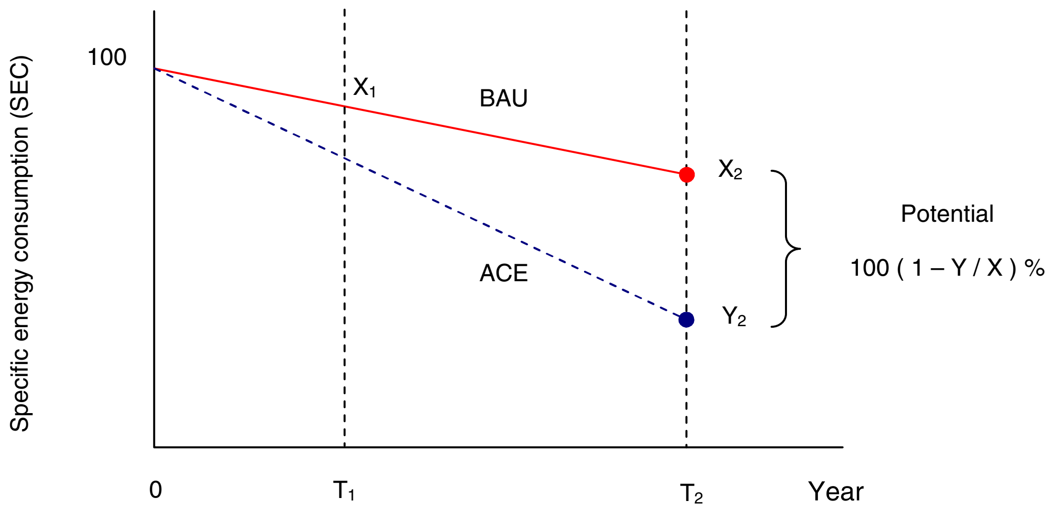

Figure 2.2 SEC trajectories

In the evaluation of the targets set under the Climate Change Agreements (DEFRA, 2001), projected SEC values under the BAU and ACE scenarios are provided for the year 2010, relative to the BAU value in the year 2000, for all of the COMETR sectors. In most cases these are at NACE level-3 (or below). However, for the Paper and Chemicals sectors the projections are only available at NACE level-2. These are shown in Table 2.2, with the final column showing the resultant estimates for the potential cost-efficient improvements in energy efficiency. Because the base-year for the projections was 1995, these represent the potential improvements over a fifteen year period, starting in that year.

There is significant variation between the sectors, with the estimated potential ranging from 8% (for Steel) to 27% (for Paper). While it is not possible to make a direct comparison with the estimates derived from the ENUSIM cost curves due the different levels of sectoral aggregation, the estimates are broadly consistent with the upper bound values shown in Table 2.1. This is to be expected, given that the model will implement any technology that provides a financial saving (i.e. has a negative net cost), no matter how small this is.[11]

[11] Note the "cost curve-based" estimates and the "projection-based" estimates are derived from different runs of the ENUSIM model with different parameter values – particularly energy price assumptions. Consequently, they are not directly comparable. If they were both derived from the same model run, one would expect the "cost curve-based" estimate of the potential to be higher given the lack of any time constraint, although there are circumstances where this may not be the case (e.g. the model can implement a technology beyond the pre-defined maximum penetration used to construct the cost curve).

Table 2.2 Sector potential

Sector		Index value 2010		Potential
		BAU	ACE	
15.1	Meat	99	89	10%
21	Paper	86	63	27%
24	Chemicals	94	73	22%
26.1	Glass	94	79	16%
26.5	Cement	95	85	11%
27.1-3	Steel	95	87	8%
27.4x	Aluminium	96	80	17%
27.4x-x	Non-ferrous metals	92	72	22%

2.4 Summary

The simulations generated by the ENUSIM model suggest that in 1995 there was a significant potential for cost-efficient improvements in energy efficiency in all of the COMETR sectors, ranging from around 10% (for Steel, Meat and Cement) to over 20% (for Non-ferrous Metals, Chemicals and Paper). However, the shape of the cost curves generated by the model also suggests that for the majority of this potential improvement, the financial savings are only marginal and hence much smaller improvements could also be consistent with cost-minimising behaviour. Consequently, these estimates should probably be treated as upper bounds for the potential.

A number of caveats are required however. First, as has already been noted, ENUSIM is a simulation model. As such, the "validity" of the projections depends on the extent to which the algorithms included in the model reflect the actual decision-making processes of firms and whether the assumed parameter values are realistic. Second, the model assumes that there are no restrictions on the availability of capital or managerial resources (such as time). To the extent that these "hidden costs" are significant, ENUSIM will overstate the potential cost-efficient improvements that can be achieved. This was certainly an argument put forward by industry during the negotiation of the targets for the Climate Change Agreements (see DEFRA, 2001). However, to a certain extent these constraints are implicitly reflected in the values that are set for the maximum final penetration of technologies and the time taken to reach 50% penetration. It should also be remembered that the technologies included in the model are only a subset of the actual technologies and behavioural changes available to firms in practice, particularly in future years. Furthermore, the model may not adequately reflect (possibly significant) reductions in the capital costs of some technologies as they move up the penetration curve. To the extent that these factors are significant, ENUSIM will understate the potential cost-efficient improvements that can be achieved.

Unfortunately it is impossible to gauge the relative importance of these factors, and hence whether the estimates generated from the model over-state, or an under-state, the potential for cost-efficient improvements in energy efficiency. However, given the scale of the estimates it seems reasonable to conclude that the potential is significantly greater than zero.

Section 3: Climate Change Agreements

All eight of the COMETR sectors are covered by Climate Change Agreements between the UK Government and the respective industry associations. Under the terms of these agreements, participating firms are required to report information on output levels and energy consumption; with aggregate information for each agreement published in the biennial assessments of performance against targets. While the agreements are not universal in their coverage, they account for the large majority of energy consumption for the respective sectors and hence the reported performance information provides a good indication of the actual improvements in energy efficiency that has been achieved by these sectors. This *ex post* evidence provides a valuable comparator for the *ex ante* estimates of the potential for cost-efficient improvements derived from the ENUSIM model.

Following a brief overview of the agreements, the performance of each sector is reviewed in turn. Unfortunately the reported information does not include any information on costs and savings, so it is not possible to directly assess the cost efficiency of the reductions in specific energy consumption. To gain some insights into this issue, the section concludes by attempting to estimate an upper bound for the payback periods of the investments driving the improvements in energy efficiency by comparing estimates of the resultant financial savings against sectoral capital expenditure figures.

3.1 Background

Climate Change Agreements (CCAs) were agreed between the Department for Environment, Food and Rural Affairs (Defra) and forty-four energy intensive sectors in March 2001, following two years of negotiations.[12] The legally-binding agreements last until March 2011 and set quantified targets for 2010, with milestone targets at two-yearly intervals (i.e. 2002, 2004, etc.). Sectors (and their constituent firms) were allowed to choose whether their targets related to carbon emissions or to primary energy consumption and whether they were defined in absolute or relative terms. The large majority chose relative targets for energy consumption – i.e. specific energy consumption (SEC). Provided that they achieve their milestone targets, CCA participants are "certified", entitling them to receive an 80% reduction in the Climate Change Levy (CCL) that was introduced in April 2001.

The agreements have a two-tier structure; with an 'umbrella agreement' between Defra and the relevant sector association, and a series of 'underlying agreements' between Defra and the constituent target units[13, 14.] Targets are set at both levels. If the sector target is achieved, then all constituent target units are deemed to have met their individual targets and are re-certified to receive the levy reduction for the following two-year period (i.e. until the next milestone). If the sector target is not met, then only those target units that have achieved their individual milestone targets are re-certified.

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[12] In the context of the agreements, the term "sectors" refers to industry associations rather than NACE classifications. Some NACE sectors are covered by more than one industry association.

[13] A target unit is a facility, or group of facilities, sharing a single target. A facility is the IPPC Stationary Technical Unit, plus any Directly Associated activities and extra items allowed under the 90/10 rule.

[14] For six sectors, the underlying agreements are between sector association and the constituent target units.

In addition to taking actions to improve their energy efficiency, participants in the CCAs can purchase allowances through the UK-ETS in order to meet their targets. If a participant over-achieves its target, then this over-achievement can either be converted into allowances (subject to verification by an accredited verifier) that can be sold, or it can be ring-fenced for future conversion (i.e. a form of banking). The agreements include three other risk management measures that can be used by participants to adjust their individual targets: product mix and output (PMO); tolerance bands; and relevant constraints. The first two of these are mutually exclusive, and both were abolished after the third milestone period (i.e. 2006).

Eligibility to enter into a CCA was originally restricted to those facilities undertaking Part A processes as specified in the Pollution Prevention and Control Regulations 2000 (PPC), though without applying the PPC size thresholds. While this had the advantage of certainty over a site's eligibility, it excluded a number of energy intensive sectors. In recognition of this anomaly, eligibility was extended in the 2004 Budget, to include other sectors that satisfy defined criteria relating to energy intensity and international competitiveness. Under the new rules, a sector is eligible to enter into an agreement if its energy expenditure exceeds 12% of its production value; or if its energy expenditure is greater than 3% and either the import penetration ratio is at least 50%, or the export to production ratio is at least 30% (i.e. it is exposed to international competition). As a result of the introduction of these new rules, ten additional sectors entered into agreements from the third milestone period onwards.

When they were introduced in 2001, the agreements covered over 5,700 target units. However, by the end of the first target period, the number of target units had fallen to around 5,000 (see Table 3.1). By the end of the second target period (i.e. April 2005) the total number of certified target units had fallen further to around 4,400 – a reduction of 23% on the original number.[15] Of the 1,300 target units leaving the agreements, around one-third were expelled (i.e. not recertified) for failing to meet their targets – either through their own efforts or by purchasing credits. The remaining two-thirds terminated their agreements voluntarily, or did not report performance information (and hence effectively terminated them).

[15] The total number of target units recertified at the end of TP2 is not broken down by agreement. Consequently, it is not possible to see how the total reduction over the first two periods is spread across sectors.

Table 3.1 Attrition during first target period

Sector	Number of Certified Target Units		
	April 2001	April 2003	% Reduction
Meat processing (15.1)	255	234	8.2%
Paper (21)	100	99	1.0%
Chemicals (24)	279	246	11.8%
Glass (26.1)	47	47	0.0%
Cement, Lime & Plaster (26.5)	18	18	0.0%
Ferrous metals (27.1-3)	20	19	5.0%
Non-Ferrous metals (27.4)	141	132	6.4%
Other	4,882	4,247	13.0%
Total	**5,742**	**5,042**	**12.2%**

Performance is assessed biennially against the interim targets. At the time of writing, the latest available assessment was for the second target period (DEFRA, 2005) and this has provided the basis for the following assessment of sector performance.

3.2 Sector performance

a) Meat processing (15.1)

The meat processing sector is covered by agreements with the *British Meat Federation* (representing the red meat sector), the *British Poultry Meat Federation*, and the *UK Renderers Association*. Initially, these umbrella agreements covered 255 target units, operating around 300 facilities; although around 8% of these had left by the end of the first target period.[16] All three agreements have targets for specific energy consumption (SEC) – expressed in kWh per tonne of production.

Figure 3.1 shows the weighted average SEC for the three agreements – with all values expressed as index values versus the business-as-usual estimate for 2000. The actual performance in the base year (1999), target period one (TP1) and target period two (TP2) are shown; as are the performance targets for each target period and the business-as-usual trend line. The final-year target represents an 11% improvement versus the projected BAU value for that year; which is itself 1% lower than the estimated value in 2000.

[16] The agreement with *Food and Drink Federation* also covers around 20meat processing facilities. However, this agreement is not included as part of the meat sector as the vast majority of constituent facilities are involved in other parts of the food and drink sector.

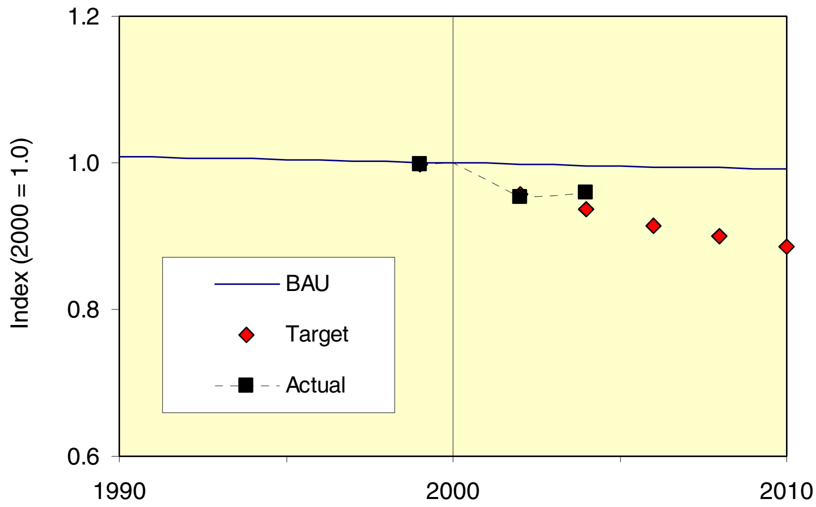


Figure 3.1 SEC trajectory for the Meat Processing sector

The sector showed a slight improvement in SEC following the introduction of the agreements in 2001. Actual performance in TP2 was 3.8% below both the base year level and the projected BAU level for that year. However, the sector missed its performance target by 2.3%; having only just met it in TP1. This was largely due to the performance of the red meat sub-sector, where SEC in 2004 was 9% above target and 2% above BAU. Together with the relatively high rate of attrition (8% during the first target period), the modest performance figures suggest that improvements in energy efficiency in the meat sector are relatively costly. This is broadly consistent with the results of the ENUSIM model, which suggested that the meat processing sector had one of the lowest potentials for cost efficient improvements in energy efficiency (see Table 2.2).

b) Paper

The paper sector is covered by agreements with the *Confederation of Paper Industries* (CPI) and the *Association of Wallcovering Manufacturers* (AWM). While the target for the former is defined in terms of specific energy consumption – expressed in kWh per tonne of production, the target for the latter is expressed in terms of absolute energy at an assumed level of throughput. Because of this, and the fact that no BAU projections are available for the latter, only the performance under the CPI agreement is considered here. However, since this agreement is by far the more significant of the two (accounting for 85% of the target units, 88% of output and 98% of energy consumption), the omission of the AWM agreement does not significantly affect the conclusions. For the CPI agreement, the final-year target represents a 5% improvement versus the projected BAU level for that year.

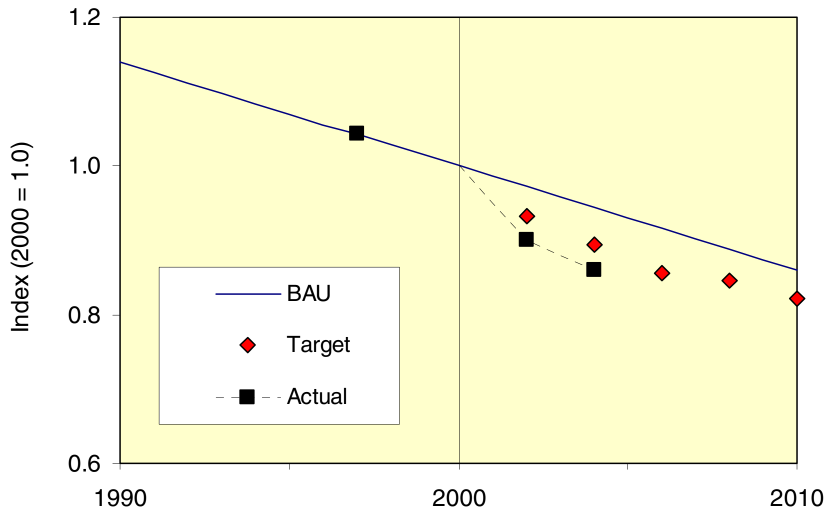


Figure 3.2 SEC trajectory for the Paper sector (Confederation of Paper Industries)

Compared to the meat processing sector, the improvement in energy efficiency by the paper sector since the introduction of the agreement in 2001 has been more significant; with SEC in TP2 being 18% lower than the base year (1997) value and 9% below the BAU value for that year. As a result, the actual performance in TP2 was 4% ahead of target.

c) Chemicals

The chemicals sector is covered by an agreement with the *Chemicals Industries Association* (CIA). Around 280 target units initially signed underlying agreements. However, the number had fallen to less than 250 by the end of TP1 – an attrition rate of almost 12%. Because of the diverse nature of the sector, targets are expressed in terms of an energy efficiency ratio (EER), which can be thought of as being equivalent to a target improvement in SEC versus the base-year for a sector producing a range of heterogeneous outputs.[17]

[17] In heterogeneous sectors it is not possible to define a meaningful common unit of output that can be used to calculate an SEC value. In these sectors, an alternative approach – based on the so-called "Novem" methodology developed in the Netherlands – was used to define targets and measure actual performance. Under this approach, an energy efficiency ratio (EER) is calculated as the weighted average of the (actual or target) values of energy consumption per unit output of individual product-lines relative to the respective base-year values; where the weights are equal to the product-lines' respective shares of total base-year energy consumption adjusted to reflect the actual production levels in the target period. The advantage of this approach is that both the actual and target EER values reflect underlying changes in energy efficiency rather than changes in the product-mix.

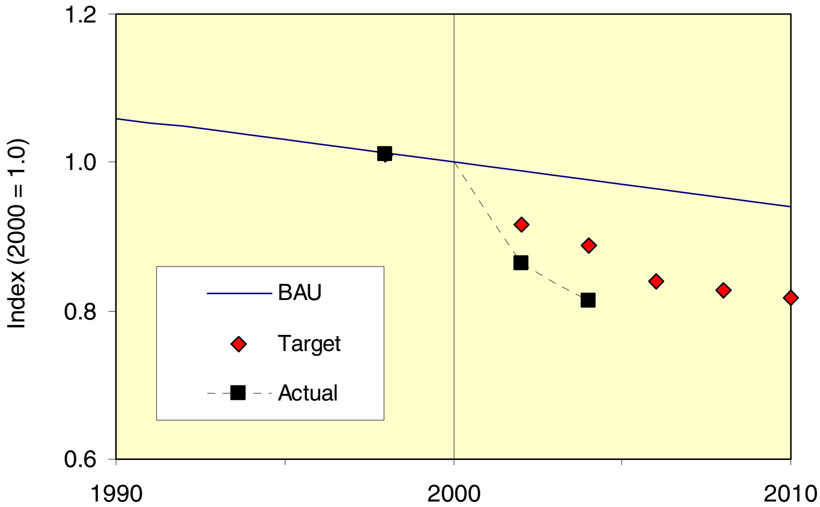


Figure 3.3 EER trajectory for the Chemicals sector

The final-year target value for the EER represents a 13% improvement versus the projected BAU value in that year[18].The reduction in the ratio since the introduction of the agreement has been significant; with the value in TP2 being almost 20% lower than the base-year (1998) values and 17% below the projected BAU value for that year. As a result of these improvements, not only did the sector beat its performance target for TP2 by more than 8%, it achieved the final (TP5) target six years ahead of schedule.

d) Glass

The agreement with the *British Glass Manufacturers Confederation* (BGMC) encompasses all manufacturing processes involving molten glass. The forty-seven target units covered by the agreement account for over 95% of the total energy consumption by the glass industry in the United Kingdom. Targets are defined in terms of SEC expressed as MWh per tonne of packed / processed glass; with the final year target representing a 6.6% improvement versus BAU in that year.

There was a significant improvement in energy efficiency following the introduction of the agreement; although all of this was achieved in the first two years, with performance levelling off thereafter. SEC in TP2 was 11.3% lower than the base year (1999) value and 8.6% below the BAU value for that year. This was reflected in a 6% over-achievement of the TP2 target.

[18] The BAU values of the EER implicitly assume that there are no changes in product-mix over the life of the agreement compared to the base-year.

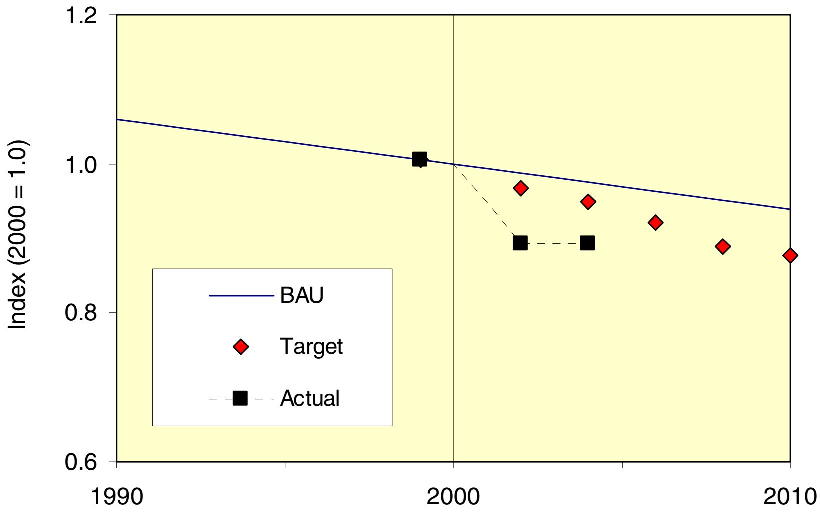


Figure 3.4 SEC trajectory for the Glass sector

e) Cement, lime and plaster

The CLP sector is covered by agreements with the *British Cement Association* (BCA), the *British Lime Association* (BLA) and the *Slag Grinders* (SGS). Together these agreements cover the production of Portland cement by all but one of the UK producers; the production of merchant lime (i.e. lime produced for sale on the open market); and the production of products from granulated blast furnace slag for the constructions and glass industries. The BCA agreement is the most significant of the three, accounting for over 80% of the combined energy consumption and 70% of combined output. The targets for all three agreements are defined in terms of SEC, expressed as kWh per tonne of production; with the weighted average final year target representing an 11% improvement versus BAU in that year.[19]

There was a steady improvement in energy efficiency following the introduction of the agreements in 2001; with the weighted average SEC in TP2 being 11.1% lower than the base year (1998/9) value and 5.9% below the target value in that year. Relative to the BAU projection, there was an 8.7% reduction in SEC.

[19] No BAU projections are available for the BLA and SGS agreements. However, given the predominance of the BCA agreement, the BAU projection for this agreement provides a reasonable proxy for the sector as a whole.

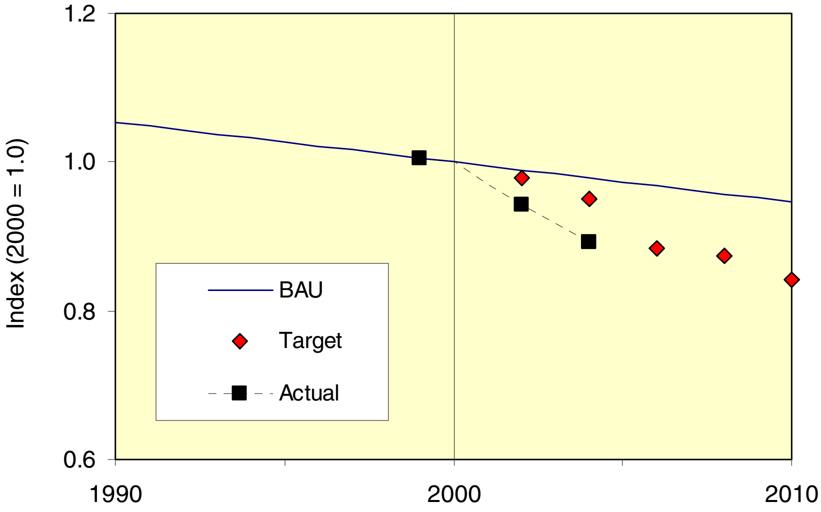


Figure 3.5 SEC trajectory for the Glass sector

f) Ferrous metals

The agreement with UK Steel (UKSEL) covers the five main steelmaking companies in the United Kingdom plus a number of smaller downstream companies. Together these account for around 98% of the sector's energy use. The target for the sector is defined in terms of absolute energy consumption, expressed as PJ. However, in the evaluation of the CCA targets (ETSU, 2001), the final year target is assessed as being equivalent to a 3% improvement in SEC versus BAU in that year. For the purposes of this analysis, this "equivalent target" has been used; with the intermediate targets assumed to follow a linear progression.

While the sector showed little improvement in the first target period, there was a dramatic reduction in TP2; leaving SEC 18.5% lower than the base-year (1997) value and 15.6% below the BAU value for that year. This sudden improvement appears to have been driven by a major restructuring of the sector, which was reflected in the composition of the UKSEL agreement. Figure 3.7 shows the number of facilities covered by the agreement, together with the reported output, energy consumption and SEC values (all converted to index values)[20]. For comparison it also shows the index of production (IOP) for the sector over the same period. As one would expect, given the high sectoral coverage of the sector in terms of output and energy consumption, there is a close correlation between the IOP and the CCA-output indices.

[20] The CCA values for output, energy consumption and SEC are only reported for 1997, 2002 and 2004, with estimated values for 2000. The dotted lines are linear interpolations between these years and do not represent actual values.

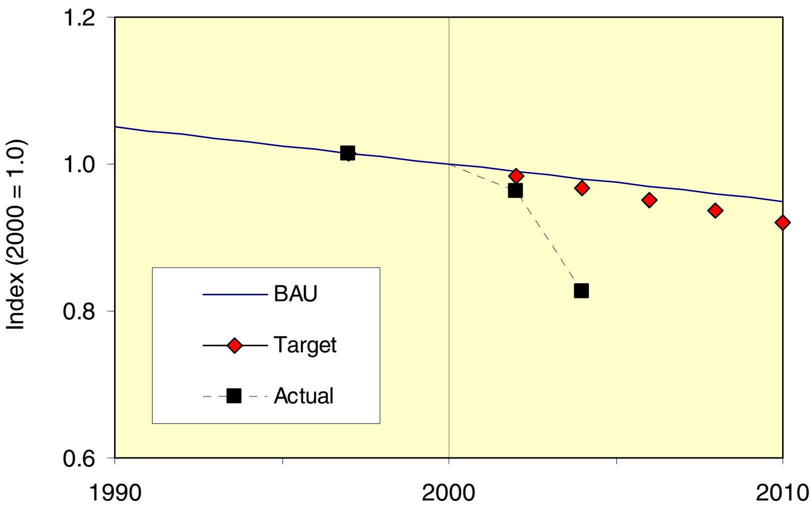


Figure 3.6 SEC trajectory for the Ferrous Metals sector

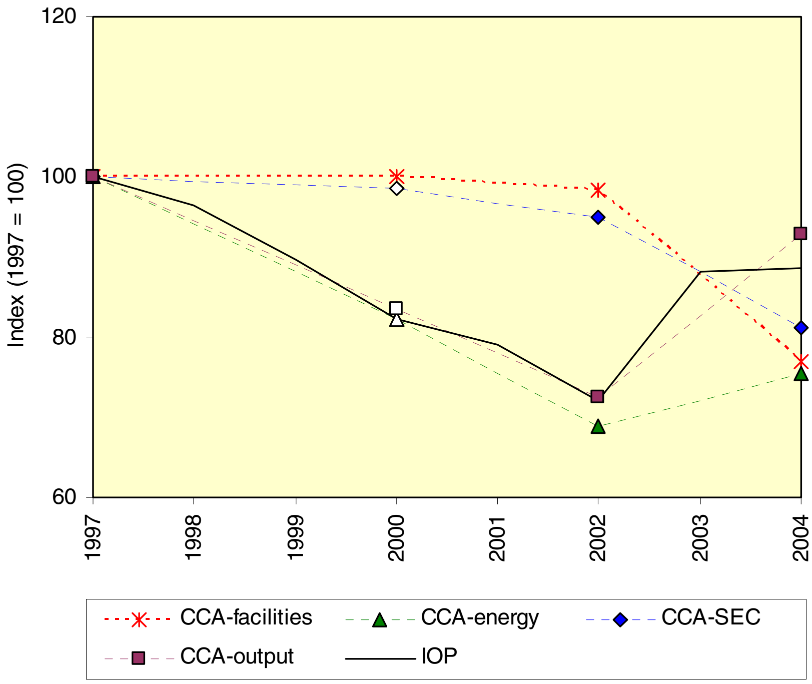


Figure 3.7 Ferrous Metals sector: energy, output and production facilities

Following a steady and significant decline in output between 1997 and 2002 there was a major upturn over the next two years, with output rising by 24%. Over the same two-year period, the number of facilities covered by the agreement fell by 22%[21]. As a result, the scale of production (i.e. output per facility) increased by more than 60%, leaving it 20% higher than in the base year. When the CCA targets were set, such significant structural changes were not foreseen. Consequently, it would be misleading to make comparisons between the actual performance and the targets from TP2 onwards, and hence none have been made for this sector.

[21] The Annual Business Inquiry shows a 40% decline in the number of enterprises in the sector over the same two-year period. While enterprises and facilities are not the same thing, it is clear that the sector underwent a major restructuring.

g) Non-ferrous metals

The non-ferrous metals sector is covered by two agreements. The agreement with the *Aluminium Federation* (ALFED) relates to the production, extruding and finishing of primary and secondary aluminium and the production of magnesium and titanium. Other parts of the sector (i.e. copper, zinc, lead and nickel) are covered by an agreement with the *Non Ferrous Alliance* (NFA). While the latter covers more target units / facilities, the ALFED agreement is much more significant in terms of energy consumption – accounting for over 80% of the combined total. The target for the ALFED agreement is defined in terms of relative carbon emissions (expressed as a ratio versus the base year), while that for the NFA agreement is defined in terms of absolute energy consumption (at an assumed level of throughput). However, as with the ferrous metals sector, equivalent SEC targets were determined for both agreements (ETSU, 2001); with the ALFED final-year target assessed as being equivalent to a 10% improvement versus BAU in that year and the NFA target as a 12% improvement.

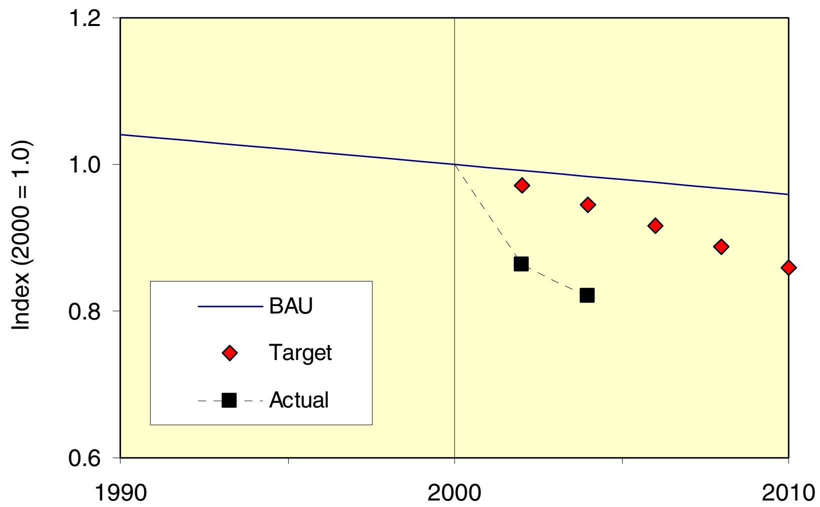


Figure 3.8 SEC trajectory for the Aluminium sector

Unfortunately the target period assessments do not provide any information on output levels for the NFA agreement and so it is not possible to assess changes in SEC over time for this agreement. For the Aluminium sub-sector however, there has been a significant improvement in SEC since the introduction of the agreement; with SEC in TP2 being more than one-third lower than the base-year (1990) level and 17% lower than the projected BAU value for that year. Compared to the "equivalent SEC target", performance in TP2 represented a 13% overachievement of the imputed target for that year and was actually 5% ahead of the final-year target.

3.3 Summary

Table 3.2 summarises the performance of the various sectors; comparing the actual performance in 2004 (TP2) against the respective base year values and against the BAU values and the CCA targets for that year. With the exception of the Meat Processing sector (15.1), there have been significant reductions in SEC versus the respective base years; with the Paper, Chemicals and Ferrous Metals sectors all achieving improvements of 15%-20% over a 6-7 year period; although, as noted above, in the last case this appears to have been driven by major structural changes. Compared to the business-as-usual counterfactual, the improvements are reduced somewhat, but still significant; ranging from

4% to 17%. This is reflected in the performance against the CCA targets; with all of the sectors (except meat processing) beating their respective targets by a considerable margin.

Table 3.2 SEC performance in Target Period 2 (2004)

		Actual performance versus		
Sector	**Base Year**	**Base Year**	**BAU_{2004}**	**$Target_{2004}$**
Meat processing (15.1)	1999	-3.8%	-3.8%	+2.3%
Paper (21)	1997	-17.5%	-8.9%	-3.9%
Chemicals (24)	1998	-19.5%	-16.7%	-8.4%
Glass (26.1)	1999	-11.3%	-8.6%	-6.0%
Cement, lime and plaster (26.5)	1999	-11.1%	-8.7%	-5.9%
Ferrous metals (27.1-3)	1997	-18.5%	-15.6%	n/a
Aluminium (27.42)	1990	-35.4%	-16.8%	-13.4%

Of course, just because the improvements in energy efficiency have been significant, it does not necessarily follow that they have been cost-efficient – i.e. that the resultant financial savings have outweighed the costs incurred. Unfortunately, the CCA returns do not include any financial information, so it is not possible to evaluate this directly. However, it is possible to provide some indications as to whether this is likely to have been the case.

Figure 3.9 plots the actual improvement in SEC versus BAU in 2004 against the cost-efficient improvement potential over the period 1995-2010 as calculated by the ENUSIM model (see Table 2.2). For five of the sectors there is a close correlation between the actual improvement versus BAU and the potential improvement calculated by the ENUSIM model. That is, those sectors with the greatest modelled potential for cost efficient improvements have achieved the greatest actual improvements. For the two outlying sectors, there are plausible explanations for the apparent lack of correlation. As noted above, the improvement in SEC for the Ferrous Metals sector appears to have been driven by significant structural changes. Since these were not included in the ENUSIM model runs underlying the calculation of the cost-efficient potential, the divergence is to be expected. For the Paper sector, the opposite is the case. A significant proportion (i.e. around 50%) of the cost-efficient potential stems from the expansion of Combined Heat and Power (CHP). Since the time-lags in implementing these investments can be lengthy is perhaps unsurprising that the actual improvement looks relatively low. If the improvements due to CHP are omitted from the potential, then the sector falls back into line.

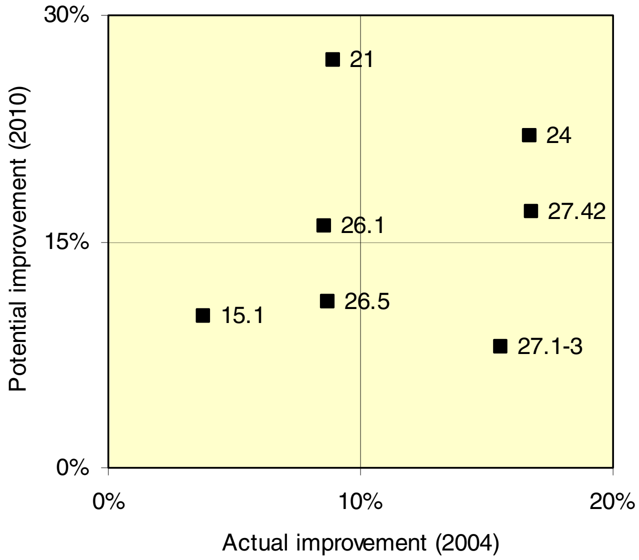


Figure 3.9: Actual improvement in SEC versus modelled cost-efficient potential

An alternative way to assess the cost-efficiency of the improvements in energy efficiency is to compare estimates of the resultant reductions in energy costs with estimates of capital expenditures in order to assess the likely magnitude of payback periods. Table 3.3 shows the calculated reductions in energy use versus the BAU counterfactual (at actual output levels) for all sectors; together with estimates of the resultant financial savings, based on estimates of respective average energy prices[22]. As can be seen, there are significant differences between the sectors; with the estimated savings ranging from less than £1 million for the Meat Processing sector to £235 million for the Chemicals sector.

Table 3.3 Estimated energy cost saving versus BAU in Target Period 2 (2004)

Sector	Ave energy price (1) (£ per TJ)	Saving versus BAU		Total CAPEX (2) (£ million)
		Energy Use (TJ)	Energy Cost (£ million)	
Meat processing (15.1)	£7,800	< 100	< 1	371
Paper (21)	£5,100	9,600	50	471
Chemicals (24)	£4,200	56,000	235	2,199
Glass (26.1)	£4,300	3,500	15	160
Cement, lime and plaster (26.5)	£3,000	5,100	15	55
Ferrous metals (27.1-3)	£3,800	57,000	215	333
Aluminium (27.42)	£5,300	10,500	55	50

Sources: (1) COMETR UK dataset;
(2) Annual Business Inquiry (gross capital expenditure before disposals)

[22] Estimates of sectoral energy prices are provided in the COMETR dataset for the United Kingdom (Work-package 3, DL3.3). The prices include taxes and are for 2002, the latest year included in the dataset.

The final column of Table 3.3 shows the total gross capital expenditure of each sector, as reported in the Annual Business Inquiry. Of course, these figures represent sectoral expenditure (unlike the cost saving estimates, which relate to agreement participants only), and they include all forms of investment, not just those made specifically to improve energy efficiency. The first issue is not too significant given the agreements' high sectoral coverage in terms of economic measures (i.e. output, costs and investment). The second issue is more significant and requires further consideration.

Table 3.4 compares the average annual levels of capital expenditure since the introduction of the agreements in 2001 with the average levels over the preceding five year period – both in terms of average expenditure per enterprise and as a share of gross value added. There is no evidence of a general increase in capital expenditure since the introduction of the agreements. Indeed, if anything there appears to have been a decline in expenditure. Only in the case of the Ferrous Metals sector has there been a noticeable increase. However, this appears to reflect a "catching-up" of investment following a significant downturn in the late 1990s.

Thus, there is no evidence to suggest that the sectors have undertaken any incremental capital expenditure as a result of the introduction of the agreements. This implies that any investments that have been made specifically to improve energy efficiency must have displaced expenditure that would have been undertaken on productive plant and equipment. While it is impossible to know the magnitude of such displacement, it seems plausible that it would not have been that great. If expenditure on energy efficiency accounted for 10%-20% of total investment, then the estimated energy cost savings shown in Table 3.3 would represent an (undiscounted) payback period of less than 2 years, which would suggest that the achieved improvements were cost-efficient[23]. Only for the Meat Processing sector is this not the case. For this sector, if energy efficiency investments accounted for only 1% of the total capital expenditure, the payback period would still be in excess of six years.

Table 3.4 Gross capital expenditure pre and post introduction of CCAs

	Gross Capital Expenditure (1)			
	per enterprise (£m)		share of GVA (%)	
Sector	1996-2000	2001-2005	1996-2000	2001-2005
Meat processing (15.1)	0.342	0.349	0.147	0.114
Paper (21)	0.241	0.202	0.174	0.136
Chemicals (24)	0.758	0.610	0.208	0.144
Glass (26.1)	0.113	0.112	0.148	0.125
Cement, lime and plaster (26.5)	1.480	1.323	0.309	0.130
Ferrous metals (27.1-3)	0.292	0.343	0.118	0.156
Non-ferrous metals (27.4)	0.205	0.217	0.141	0.125

(1) For the Cement, Lime and Plaster sector, capital expenditure is net of disposals

Source: Annual Business Inquiry

[23] For the Ferrous Metals sector, this would be the case even if all of the capital expenditure was directed at improving energy efficiency. However, caution should be exercised in interpreting this apparent result given the significant restructuring that has occurred in the sector.

The overall conclusion of the analysis of the CCA performance data is that significant improvements in energy efficiency have been achieved over a relatively short period of time. While there is no direct information on the costs and benefits of these improvements, there is *prima facie* evidence to suggest that they have been cost-efficient – at least for most sectors. There is a close correlation between the magnitudes of the improvements achieved by the sectors and the cost-efficient potentials derived from the ENUSIM model. There is no evidence of any incremental capital expenditure being undertaken and under plausible assumptions about the displacement of productive investment, the estimated reductions in energy costs imply very short payback periods. The one exception to this is the Meat Processing sector. For this sector, the high attrition rate, poor performance versus BAU and target, minimal energy savings and relatively long payback periods suggest that improvements in energy efficiency are costly.

It might be tempting to conclude that the over-achievement of the CCA targets shown in Figures 3.1 – 3.8 (up to six years ahead of schedule in some cases) means that these targets are cost efficient – i.e. that they can be achieved without incurring any net cost. However, as will be shown in the next section, this does not necessarily follow.

Section 4: Theoretical model of firm behaviour

In this final section, a theoretical model is used to explore how a cost-minimizing firm might be expected to behave. In particular, the analysis focuses on the time-profile of energy efficiency expenditures and whether the resultant trajectory for the firm's specific energy consumption (SEC) can provide any indication of the costliness of regulatory targets for energy efficiency.

Following the definition of the underlying model, the cost-minimizing behaviour of the firm is analysed in the absence of any regulation. The impact of regulation (in the form of a series of energy efficiency targets) on the firm's behaviour is then considered, under varying degrees of regulatory flexibility. A simple numerical simulation is then used to illustrate the analytical results.

4.1 Model definition

The quantity of energy in Joules (z_t) used by the firm in time period (t) is determined by its output level in that period (Y_t) and its specific energy consumption (ρ_t). Specific energy consumption (SEC) is assumed to exhibit an underlying "business-as-usual" (BAU) trend over time. This is likely to be downwards (but not necessarily so); reflecting improvements arising from general commercial decisions without any particular consideration of energy efficiency. However, it can be reduced below the BAU level by investing in energy efficiency "capital". This may take the form of physical capital or human capital (i.e. knowledge), and is assumed to depreciate at a constant percentage rate[24,25]. Hence:

[24] For physical capital, expenditure represents the difference in cost between the energy-efficient technology and the counterfactual technology (i.e. the technology that would have been installed in the absence of any specific consideration of energy efficiency), with any differences in operating costs being capitalised. For human capital, expenditure represents the (capitalised) cost of staff training, etc.

[25] In order to simplify notation, the model is defined in terms of the persistence rate (i.e. the proportion of capital remaining) rather than the depreciation rate.

$$\rho_t = \rho_t(E_t) \quad \text{where} \quad E_t = \gamma E_{t-1} + e_t = \sum_{\tau=1}^{t} \gamma^{t-\tau} e_t \qquad \ldots (1)$$

It is assumed that $0 < \gamma < 1$ (i.e. expenditure always has some impact on future periods, but this diminishes over time), and that $\rho_t(E_t)$ is strictly convex and continuously differentiable with $\rho_t'(E_t) < 0$.

It follows directly from (1) that an increase in expenditure in any period affects the SEC in that period and in all future periods; with future impacts depending on the value of the persistence parameter (γ), i.e.

$$\frac{\partial \rho_{t+k}}{\partial e_t} = \rho_{t+k}'(E_{t+k}) \frac{\partial E_{t+k}}{\partial e_t} = \rho_{t+k}'(E_{t+k}) \, \gamma^k \qquad \text{for all } k \geq 0 \qquad \ldots (2)$$

Regulation takes the form of a series of annual SEC performance standards (r_t) over a fixed time horizon of T years; which are assumed to decline over time and which are more stringent than the BAU values in each year. In addition, the regulation includes the following two potential flexibility mechanisms:

- *banking*: over-performance (against the target) in any period can be carried forward by the firm and used to offset any under-performance in future periods;
- *trading*: under-performance in any period may be offset by purchasing energy performance credits from other firms, while over-performance may be converted into credits and sold to other firms.

While these flexibility options are made available under the regulation, the firm does not have to make use of them and it may choose (for a variety of potential reasons) to use only one, or neither of the options.

The firm chooses its "energy plan" (i.e. combination of energy input quantities, energy efficiency investments and – where relevant – energy performance credit transfers) for the entire regulatory horizon in year 0 – with the plan starting in year 1. The plan is based on forecasts of its output levels over this horizon, together with the prices of energy and energy performance credits; both of which are taken as given (i.e. exogenous). It also takes account of the present value of the expected future benefits arising from the energy efficiency capital remaining at the end of the regulatory horizon (i.e. E_T).

4.2 No regulation

In the absence of any regulation, the objective of the firm is to minimize the present value of its combined expenditure on energy consumption and efficiency improvements, given its forecasts of output levels and energy prices over the planning horizon. Formally, the cost minimization problem is:

$$\text{Minimize} \qquad \sum_{t=1}^{T} \delta^t \left[p_t z_t + e_t \right] + \delta^T C_T(E_T)$$

Subject to $\rho_t(E_t)\, Y_t \;-\; z_t \;\leq\; 0$ … (C1a)

$$E_t \;-\; e_t \;-\; \gamma E_{t\text{-}1} \;\leq\; 0 \qquad \text{… (C1b)}$$

$$z_t \geq 0 \quad e_t \geq 0 \quad E_t \geq 0 \qquad [E_0 = 0] \qquad \text{for all } t = 1, \dots, \mathrm{T}$$

where $C_T(E_T)$ is the expected present value at time T of future energy costs and energy efficiency investments, conditional on the value of energy efficiency capital at that time. Denoting the Lagrange multipliers for constraints (C1a) by μ_t, and for constraints (C1b) by η_t, the Kuhn-Tucker complementary slackness conditions are:

$$z_t \geq 0 \qquad -\delta^t\, p_t \;+\; \mu_t \;\leq\; 0 \qquad \text{… (2a)}$$

$$e_t \geq 0 \qquad -\delta^t \;+\; \eta_t \;\leq\; 0 \qquad \text{… (2b)}$$

$$E_t \geq 0 \qquad -\rho_t'(E_t)\, Y_t\, \mu_t \;-\; \eta_t \;+\; \gamma\, \eta_{t+1} \;\leq\; 0 \qquad \text{… (2c)}$$

$$E_T \geq 0 \qquad -\rho_T'(E_T)\, Y_T\, \mu_T \;-\; \eta_T \;-\; \delta^T\, C_T'(E_T) \;\leq\; 0 \qquad \text{… (2d)}$$

Under the assumptions that have been made about $\rho_t(E_t)$, these conditions are both necessary and sufficient for a solution[26]. Furthermore, since all of the constraint functions (C1a) are binding, the solution is unique.

If, as seems reasonable, $C_T(E_T)$ is the value function for a cost minimization problem with a similar structure to the above, then $C_T'(E_T) = -\gamma\delta$ if the firm has positive investment expenditure in year T+1, and $-\gamma\delta < C_T'(E_T) < 0$ if it does not[27]. Furthermore, assuming that energy is an essential input, then the firm must use some energy in each period (i.e. $z_t > 0$ for all t) and hence $\mu_t = \delta^t\, p_t$ for all t. That is, the marginal benefit of a reduction in (total) energy consumption in any period is equal to the discounted value of the energy price.

Consider any year $t = \tau$ in which $e_\tau > 0$ (i.e. there is positive expenditure on energy efficiency). It follows that $\eta_\tau = \delta^\tau$ and $E_\tau > 0$, and therefore that:

$$\delta^\tau\, [\, 1 \;+\; \rho_\tau'(E_\tau)\, Y_\tau\, p_\tau \,] \;=\; \gamma\, \eta_{\tau+1} \qquad \text{… (3)}$$

---

[26] Note: the Slater constraint qualification is satisfied as the constraint set defined by (C1a) and (C1b) has a non-empty interior and all binding constraint functions are convex.

[27] The cost minimization problem at time T can have different parameter values (apart from γ and δ) and can include additional constraints, such as regulatory constraints, so long as these do not include E_T. However, the constraint on the change in energy efficiency capital (C1b) must be the same.

Since $\gamma > 0$ by assumption, it follows that $E_t > 0$ for all $t = \tau, \ldots, T$, and therefore that:

$$\left.\begin{aligned} \eta_{\tau+k} &= -\rho_{\tau+k}'(E_{\tau+k})\, Y_{\tau+k}\, \delta^{\tau+k}\, p_{\tau+k} + \gamma\, \eta_{\tau+k+1} \\ &\text{for} \quad k = 1, \ldots, T-\tau-1 \\ \eta_T &= -\rho_T'(E_T)\, Y_T\, \delta^T\, p_T - \delta^T\, C_T'(E_T) \end{aligned}\right\} \qquad \ldots (4)$$

Substituting iteratively and rearranging the resultant expression yields:

$$1 = -\frac{\partial \rho_\tau}{\partial e_\tau} Y_\tau p_\tau - \sum_{t=\tau+1}^{T} \delta^{t-\tau} \frac{\partial \rho_t}{\partial e_\tau} Y_t\, p_t - \delta^{T-\tau} \frac{\partial C_T}{\partial e_\tau} \qquad \ldots (5)$$

The left-hand side is the marginal cost of expenditure. The first term on the right-hand side is the marginal benefit of the expenditure arising in the current period (note that the derivative is negative); the second term is the present value of the marginal benefits arising over the rest of the regulatory horizon; while the final term is the present value of the marginal benefit arising after the end of the regulation. Thus, in deciding how much to spend on improving energy efficiency, the firm takes into account both the benefits in the current period and "carry-over" benefits in the future. It follows directly that the right-hand side of (3) represents the value of future benefits at time τ, discounted back to the present time (i.e. $t = 0$).

Together, conditions (2b) and (3) imply that:

$$-\frac{\partial \rho_\tau}{\partial e_\tau} Y_\tau p_\tau \geq 1 - \gamma\delta \qquad \ldots (6)$$

That is, there is a <u>lower bound for the current period benefit</u> in year τ equal to $1 - \gamma\delta$. Conversely, there is an <u>upper bound for future period benefits</u> equal to $\gamma\delta$.

Now consider the <u>previous year</u> ($t = \tau - 1$) and assume that there had been no investment in energy efficiency capital by the end of that year (i.e. τ is the first period in which investment occurs). It follows directly from (2b), (2c) and (6) that:

$$-\frac{\partial \rho_{\tau-1}(0)}{\partial e_{\tau-1}} Y_{\tau-1}\, p_{\tau-1} \leq -\frac{\partial \rho_\tau(E_\tau)}{\partial e_\tau} Y_\tau\, p_\tau$$

which can be rearranged to give

$$\frac{\sigma_{\tau-1}(0)}{\sigma_\tau(E_\tau)} \leq \frac{\rho_\tau(E_\tau)\, Y_\tau\, p_\tau}{\rho_{\tau-1}(0)\, Y_{\tau-1}\, p_{\tau-1}} \qquad \ldots (7)$$

where $\sigma_t = \dfrac{\partial \rho_t(E_t)}{\partial e_t} \Big/ \rho_t(E_t)$

The left-hand side of (7) is equal to the ratio of the percentage changes in specific energy consumption arising from a marginal increase in energy efficiency expenditure. It is straightforward to show that since $\rho_t(E_t)$ is convex, the magnitude of the percentage change (note: it is negative) declines as cumulative expenditure increases. Thus, provided that the percentage change in SEC does not increase significantly between the two years (for a given level of cumulative expenditure), the value of the ratio is greater than one[28]. The right-hand side is equal to the ratio of the energy expenditures in the two periods. If the improvement in energy efficiency resulting from the investment in time τ is sufficiently great to outweigh any increases in output and / or energy prices, then this ratio will be less than one. As will be seen in the illustrative example below, this is not guaranteed to be the case. However, in practice one might commonly expect it to be the case – particularly since there has been no previous investment in energy efficiency measures (by assumption). In which case the underlying assumption cannot be true, and there must have been expenditure in some previous time period. By induction, it follows directly that expenditure in the first time period (t = 1) must be positive.

Having made an investment in period τ, will the firm make further investments in energy efficiency in any (or all) of the subsequent periods? It follows from conditions (3) and (4) that a necessary condition for the firm to make an investment in period τ + K ($0 < K \leq T-\tau$) is that:

$$1 - (\gamma\delta)^K = -\sum_{k=0}^{K-1} \delta^k \frac{\partial \rho_{\tau+k}}{\partial e_\tau} Y_{\tau+k}\, p_{\tau+k} \qquad \ldots (8)$$

Thus a necessary condition for the firm to undertake investment expenditure in period τ + K is that in period τ, the discounted benefits over the first K periods (including the current benefit in that period) must be equal to $1 - (\gamma\delta)^K$. In particular, the firm will only make a further investment in the following period (K=1) if the current period benefit in period τ is equal to the lower bound. It follows that a necessary condition for the firm to invest in every period from τ until the end of the regulatory horizon is that the current period benefit is equal to the lower bound ($1 - \gamma\delta$) in each period. However, the profile of the discounted benefits across periods is determined by the exogenous model parameters (i.e. γ, δ, $\mathbf{Y}$, $\mathbf{p}$) and – as will be seen in the illustrative example below – it is possible that there is no value of K for which (8) is satisfied. In this case, the firm only undertakes investment in a single period (i.e. period τ).

4.3 Regulation

In the presence of the regulation, the objective of the firm is to minimize the present value of its combined expenditure on energy consumption, efficiency improvements and performance credits over the planning horizon (i.e. T years); subject to satisfying the regulatory constraint; given its forecasts of output levels, energy prices and performance credit prices. Formally, the cost minimization problem is:

[28] For a given level of cumulative expenditure it is perfectly possible for specific energy consumption to be changing while the percentage change in specific energy consumption remains constant. For example, this is the case for $\rho_t(E_t) = \exp[\alpha t - \beta E]$, where the percentage change is equal to β. It should also be noted that any change between consecutive years is unlikely to be significant.

$$\text{Minimize} \quad \sum_{t=1}^{T} \delta^t \left[p_t z_t + e_t + q_t v_t \right]$$

$$\text{Subject to} \quad \rho_t(E_t)\, Y_t - z_t \leq 0 \qquad \text{… (C2a)}$$

$$E_t - e_t - \gamma E_{t-1} \leq 0 \qquad \text{… (C2b)}$$

$$\rho_t(E_t)\, Y_t + (B_t - B_{t-1}) - v_t \leq L^r \quad [\equiv r_t Y_t\ ] \qquad \text{… (C2c)}$$

$$z_t \geq 0 \quad e_t \geq 0 \quad E_t \geq 0 B_t \geq 0 [E_0 = 0] \quad [B_0 = 0]$$

for all $t = 1, \dots, T$

This definition of the problem assumes that the firm uses both of the flexibility mechanisms allowed under the regulation (i.e. trading and banking). Rather than define separate optimization problems for the cases where the firm chooses not to use these mechanisms, it is more convenient (and instructive) to model these cases by adding the constraints:

$$|\, v_t \,| \leq L_v \qquad [\, L^v = 0 \text{ or } \infty] \qquad \text{… (C2d)}$$

$$B_t \leq L_B \qquad [\, L^B = 0 \text{ or } \infty] \qquad \text{… (C2e)}$$

where the values of the constants on the RHS of the inequalities are set equal to ∞ if the firm uses the respective flexibility mechanism, and equal to 0 if it does not[29].

Denoting the Lagrange multipliers for constraints (C2c) by λ_t, for constraints (C2d) by α_t, and for constraints (C2e) by β_t, then the Kuhn-Tucker complimentary slackness conditions are:

$$z_t \geq 0 \qquad -\delta^t p_t + \mu_t \leq 0 \qquad \text{… (9a)}$$

$$e_t \geq 0 \qquad -\delta^t + \eta_t \leq 0 \qquad \text{… (9b)}$$

$$E_t \geq 0 \quad -\rho_t'(E_t)\, Y_t\, (\mu_t + \lambda_t) - \eta_t + \gamma\, \eta_{t+1} \leq 0 \qquad \text{… (9c)}$$

$$E_T \geq 0 \quad -\rho_T'(E_T)\, Y_T\, (\mu_T + \lambda_T) - \eta_T - \delta^T C_T'(E_T) \leq 0 \qquad \text{… (9d)}$$

$$v_t \qquad -\delta^t q_t + \lambda_t - \alpha_t = 0 \qquad \text{… (9e)}$$

$$B_t \geq 0 \quad -\lambda_t + \lambda_{t+1} - \beta_t \leq 0 \qquad \text{… (9f)}$$

$$B_T \geq 0 \quad -\lambda_T - \beta_T \leq 0 \qquad \text{… (9g)}$$

If the firm uses both of the flexibility mechanisms then $\alpha_t = 0$ and $\beta_t = 0$ for all t (Note: this does not necessarily imply that $v_t \neq 0$ or $B_t > 0$ for all t). If it only uses banking, then $\beta_t = 0$; with $\alpha_t > 0$ if it would have been a buyer if it had traded, and $\alpha_t < 0$ if it would have been a seller. If the firm does not

[29] Note that when L_B is set to zero, (C2e) and the non-negativity constraint imply that that $B_t = 0$ for all t.

use banking, then $\beta_t > 0$ if it would have done so in the absence of the constraint. Rearranging (9e) and (9f) gives:

$$\lambda_t \quad = \quad \delta^t q_t \; + \; \alpha_t \quad \geq \quad 0 \qquad \ldots (9e')$$

$$\lambda_{t+1} \; \leq \quad \lambda_t \; + \; \beta_t \qquad \ldots (9f')$$

Thus, if the firm takes advantage of both flexibility mechanisms, then the shadow value of the regulatory constraint in any period is equal to the discounted permit price in that period. In this case, a necessary condition for the problem to have a finite solution is that the discounted permit price is non-increasing. If the discounted price increases between any two periods, the possibility for arbitrage will mean that the firm will want to purchase an infinite quantity of permits in the first period, bank them, and sell them back to the market in the second period. It should be noted, that it is the availability of banking that allows this. If the firm does not make use of this mechanism, then the constraint on expected permit prices is not required.

If the firm makes use of the banking facility, then (9f′) implies that if the regulation is binding in a particular period, it must also be binding in all previous periods. In particular, if it is binding in the final period, then it is binding in all periods. However, if it does not use the banking facility, this does not necessarily follow.

The Kuhn-Tucker condition for the regulatory constraint is:

$$\lambda_t \;\; [\; (\rho_t(E_t) - r_t) \, Y_t \; + \; (B_t - B_{t-1}) \; - \; v_t \;] \quad = \quad 0$$

Thus, if the firm uses either of the two flexibility mechanisms, then it is perfectly possible for actual SEC to be lower than the target value (or higher) even when the constraint is binding (i.e. $\lambda_t > 0$). Only if the firm does not take advantage of either flexibility mechanism does over-achievement of the target indicate that the constraint is not binding.

Consider any period $t = \tau$ in which there is positive expenditure on energy efficiency. The derivation of the solution is analogous to the non-regulation case, yielding:

$$1 \quad = \quad - \frac{\partial \rho_\tau}{\partial e_\tau} \, Y_\tau \, (p_\tau + \lambda_\tau^{\#}) \; - \; \sum_{t=\tau+1}^{T} \delta^{t-\tau} \frac{\partial \rho_t}{\partial e_\tau} \, Y_t \, (p_t + \lambda_t^{\#}) \; - \; \delta^{T-\tau} \frac{\partial C_T}{\partial e_\tau} \qquad \ldots (10)$$

where $\lambda_t^{\#} = \lambda_t / \delta^t$

When the firm takes its output values as fixed, then the only impact of the introduction of the SEC standards is to raise the effective price of energy in the periods where the standards are binding (i.e. $\lambda_t > 0$). This is equivalent to introducing an energy tax in each period, equal to $\lambda_t^{\#}$. Thus, if the regulation is binding in the period, the value to the firm of reductions in energy use is higher than when there is no regulation. If the firm undertakes energy efficiency expenditure in every period with, or without regulation, then:

$$-\frac{\partial \rho_t}{\partial e_t}^{*} Y_t\, p_t \quad = \quad 1 - \gamma\delta \quad = \quad -\frac{\partial \rho_t}{\partial e_t}^{\#} Y_t\,(\, p_t + \lambda_t^{\#}\,) \qquad \text{for all } t$$

where the superscripts # and * denote the values of the partial derivatives with and without regulation. Thus

$$\rho_t'(E_t^{*}) \quad \leq \quad \rho_t'(E_t^{\#}) \qquad \text{for all } t$$

Since $\rho_t(E_t)$ is decreasing and convex by assumption, this implies that the stock of energy efficiency capital is higher under regulation in every period in which the regulatory constraint is binding. Thus, if the constraint is binding in the final period, then the stock will be higher in every period. Note that this does not necessarily imply that expenditure is higher in every period.

Rearranging (10) and invoking the implicit function theorem yields:

$$\lambda_\tau^{\#} \quad = \quad \left[-\frac{de_\tau}{d\rho_\tau}\right] \;-\; \left[\, Y_\tau\, p_\tau \;+\; \sum_{t=\tau+1}^{T} \delta^{t-\tau}\left[-\frac{de_\tau}{d\rho_\tau}\right]\frac{\partial \rho_t}{\partial e_\tau}\; Y_t\,(\, p_t \;+\; \lambda_t^{\#}\,)\,\right] \qquad \ldots (11)$$

The first term on the right-hand side of (11) is the marginal cost of reducing specific energy consumption. The second expression (inside the square brackets) is the marginal benefit arising from the reduction. This has two components: the marginal benefit in the current period, equal to the reduction in the cost of energy used; the marginal benefit in the future, equal to the discounted value of the sum of the reductions in energy expenditures and the reduction in future regulatory costs. Thus, the shadow value $\lambda_\tau^{\#}$ is equal to the excess of the marginal cost of improving energy efficiency over the marginal benefit.

The behaviour of the firm and the information that can be gleaned about the stringency of the regulation (i.e. whether any or all of the regulatory constraints are binding) depends on the extent to which it makes use of the flexibility mechanisms available under the regulation. There are three cases to consider.

Case a) Firm uses banking and trading mechanisms

If the firm takes advantage of both banking and trading, then $\alpha_t = \beta_t = 0$ and $\lambda_t = \delta^t q_t$ for all t. In this case, the regulatory constraint is binding in each period; with the marginal cost of improving energy efficiency being equal to the discounted permit price .

The firm's behaviour with respect to performance credits depends on its expectations about the trajectory for credit prices. If it expects the discounted price of permits to fall over time (as would be the case if the price remains constant in nominal terms), then $\lambda_t > \lambda_{t+1}$, which implies that $B_t = 0$ for all

t. That is, the firm always sells as many credits as it can in each period (or purchase as few as it needs) and does not bank any.

If the firm expects the discounted price to remain constant over time, then $\lambda_t = \lambda_{t+1}$. In this case, all of the banked permits are used, or sold, by the end of the regulatory horizon (i.e. $B_T = 0$). However, for the intervening periods, the firm is indifferent between buying / selling permits and building up / running down the permit bank, subject of course to the non-negativity constraint on the bank. It does not matter to the firm whether it sells a permit now, or banks it and sells it later. Consequently, only the net permit purchases: $v_t + (B_{t-1} - B_t)$ can be derived (i.e. including permits "purchased" from, or "sold" to the bank).

Case b: Firm uses banking mechanism only

If the firm takes advantage of the banking facility then $\beta_t = 0$. In which case, the Kuhn-Tucker conditions (9f) and (9g) simplify to:

$$B_t \geq 0 \quad \lambda_{t+1} - \lambda_t \leq 0 \qquad B_t [\lambda_{t+1} - \lambda_t] = 0 \qquad \ldots (9f'')$$

$$B_T \geq 0 \quad - \lambda_T \leq 0 \qquad B_T [\lambda_T] = 0 \qquad \ldots (9g'')$$

Thus, the sequence of shadow values (λ_t) is weakly decreasing; with the value in the final period (λ_T) providing the lower bound. If the quantity of banked permits held by the firm at the end of the final period is strictly positive than the shadow value for this period is zero. If no permits are held at the end of the period, then the shadow value is greater than (or possibly equal) to zero. The values for the intervening periods (t = 1, … , T-1) depends on whether the number of banked permits falls to zero in any of the periods. If the number of banked permits is positive in every period, then the shadow value of the regulatory constraint for each period is the same as for the final period. If it is zero in a particular period, then the shadow value in that period – and all preceding periods – is greater than (or possibly equal to) the value in the succeeding period. For example, if the permit bank falls to zero in period 2 and 5, then:

$$\lambda_1 = \lambda_2 \geq \lambda_3 = \lambda_4 = \lambda_5 \geq \lambda_6 = \ldots = \lambda_T \geq 0$$

Thus, if the number of permits banked is positive in very period – including the final period, then the marginal cost of energy efficiency improvements is zero in every period.

If the bank remains positive throughout the regulatory horizon then $\alpha_t = -\delta^t q_t < 0$ in every period; which implies that the firm would have been a seller of permits if it had taken advantage of the trading mechanism in that period.[30] If the bank falls to zero in any period, then the discounted credit price in that period – and all preceding periods – provides a lower bound for the marginal cost if the firm would have been a buyer of credits had it taken advantage of the trading mechanism (i.e. $\alpha_t > 0$), and an upper bound if it would have been a seller (i.e. $\alpha_t < 0$). The direction of trading in any period will

[30] The sign of α_t denotes whether the firm would buy or sell performance credits if the trading constraint was to be relaxed for that period only. It does not necessarily indicate the direction of trading in that period if the constraints were to be relaxed in all periods – as is the case when the firm utilizes the trading mechanism.

of course depend on value of the discounted credit price relative to the firm's marginal cost and there is little that can be said in general. However, it follows directly from 9(e) and 9(f) that:

$$\alpha_t - \alpha_{t-1} \quad \leq \quad \delta^{t-1} q_{t-1} - \delta^t q_t \quad \text{if} \quad B_t = 0$$

$$= \quad \delta^{t-1} q_{t-1} - \delta^t q_t \quad \text{if} \quad B_t > 0$$

Since the discounted price of performance credits is non-increasing, so too is the shadow value of the trading constraint (α_t). Consequently, if in the last period in which the bank falls to zero, the firm would wish to buy credits if the trading constraint in that period was to be relaxed, then it would also wish to buy in every preceding period if the respective constraints were relaxed. In this case, the discounted credit prices in each of these periods provide lower bounds for the respective marginal costs. Similarly, if the firm would wish to sell credits in period 1 if the trading constraint was to be relaxed in that period, then it would wish sell credits in every period. In this case, the discounted credit prices provide upper bounds for the marginal costs. A corollary of this is that it is not possible that the firm would wish to sell credits in the first period if the trading constraint was to be relaxed in that period, but to buy them in the last period in which the bank falls to zero. However, the opposite is possible.

Case c: The firm does not use either mechanism

If it does not take advantage of the banking facility, then $B_t = 0$ for all t. In this case, $\lambda_t = 0$ if $\rho_t(E_t)\, Y_t < L^r$, but if the constraint is binding then all that can be inferred is that:

$$\lambda_t \quad = \quad \delta^t q_t + \alpha_t \quad \geq \quad -\sum_{t=\tau}^{T} \beta_t$$

Since the right-hand side of the inequality is negative, it is not possible to deduce anything about the marginal cost from the discounted permit price. This of course is not very surprising.

4.4 Simulation

A simple numerical simulation is used to supplement the analytical results derived above and to explore how the behaviour of the firm may differ depending on the stringency of the SEC targets set under the regulation. Two cases are considered. In the first case, the final year target is set lower than the cost-minimising SEC in the absence of regulation (i.e. the target is "binding"); in the second, it is set higher than the cost-minimising SEC (i.e. it is "non-binding"). Six scenarios are considered under each case:

- no regulation, business-as-usual (BAU)
- no regulation, cost minimization (CMIN-U)
- regulation, no flexibility (CMIN-R (Model A))
- regulation, banking (CMIN-R (Model B))
- regulation, full flexibility, constant nominal price (CMIN-R (Model C1))
- regulation, full flexibility, constant discounted price (CMIN-R (Model C2))

Under the first scenario, the firm does not make any investments in energy efficiency improvements and hence specific energy consumption (SEC) continues its business-as-usual (BAU) trend; while under the second, the firm spontaneously undertakes investments so as to minimize the discounted sum of it energy costs and energy efficiency expenditures over its planning horizon. Under the other four scenarios the firm minimizes its total costs subject to satisfying annual SEC targets imposed under the regulation. In the first of these, it makes no use of the flexibility mechanisms allowed under the regulation; while in the second, it uses the banking mechanism to carry-forward any over performance. In the last two, the firm additionally uses the trading mechanism, assuming respectively that the nominal price of energy performance credits remains constant (Model C1) or that the discounted price remains constant (Model C2).

The SEC function takes the exponential functional form: $\rho_t(E_t) = \text{EXP}(\alpha t + \beta E_t)$. Hence, a unit increase in either time or energy efficiency investment causes a constant percentage change in SEC (given by α and β respectively). Apart from the values of the targets, the model parameters are the same in both cases. These are given in Table 4.1.

Table 4.1: Parameter values

Model parameter		Value	Growth
Planning horizon (years)	T	5	-
Discount factor	δ	0.9	-
Output (base year)	Y_0	10	5%
Energy price (base year)	p_0	1.0	0%
EPC price (base year)	q_0	0.1	0% / 11%
BAU trend	α	-0.01	-
EEC impact	β	-0.02125	-
EEC persistence factor	γ	0.9	-

The firm has a five year planning horizon[31] and uses a discount factor of 0.9 (i.e. an interest rate of 11%). It assumes that output will grow (from its base year value) at a constant rate of 5% per annum over the planning horizon, while energy prices will remain unchanged. The price of an energy performance credit is one tenth of the energy price in the base year, and is either expected to remain unchanged or to grow in line with the interest rate (i.e. the discounted price remain constant). In the absence of any energy efficiency investment, specific energy consumption (SEC) improves at a business-as-usual (BAU) rate of 1% per annum. A unit increase in energy efficiency expenditure reduces SEC in the current period by 2.125%, with the impact depreciating at a constant rate of 10% per annum.

Figure 4.1 shows how the cost-minimizing trajectories for SEC and investment expenditure under the CMIN-U scenario (i.e. in the absence of regulation) are affected by changes in three of the model

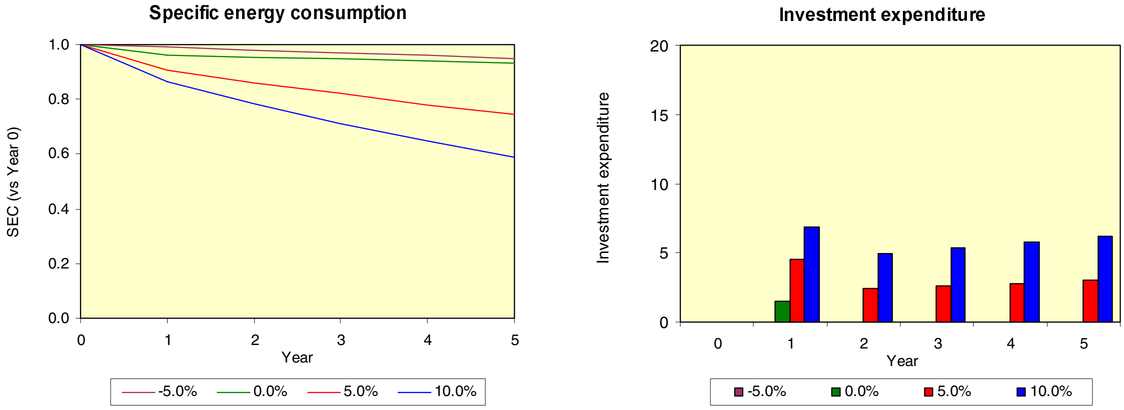
[31] The planning horizon is defined in terms of years for simplicity. However, it could be defined in terms of bi-annual target periods (i.e. as in the CCAs). This would not change any of the results, but would require suitable changes to the interpretation of the parameter values.

parameter values (output growth, persistence factor and impact factor); with each parameter being varied around its base value in turn.[32, 33] While these sensitivity analyses are not exhaustive, they demonstrate that a wide range of outcomes can be consistent with cost-minimizing behaviour in the absence of regulation.

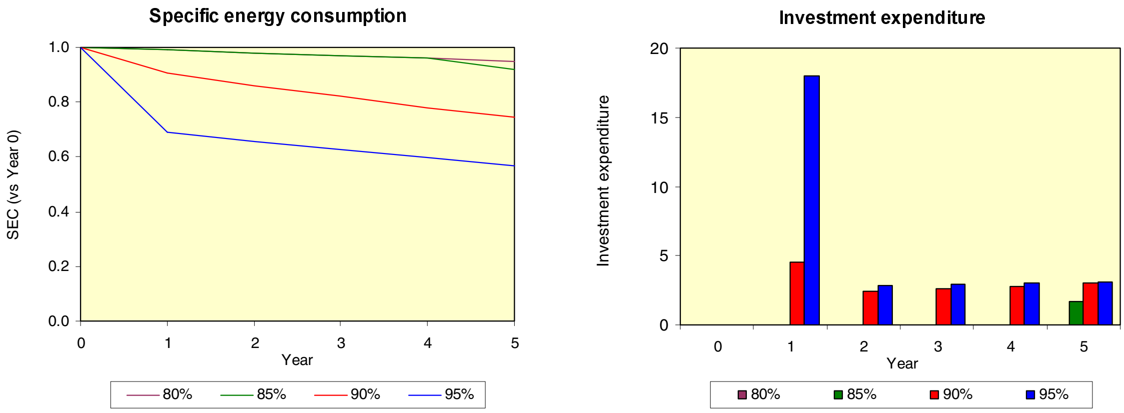
[32] The simulation results underlying Figures 4.1, 4.2 and 4.3 are provided in Annex B.

[33] Note: the base value used for the impact factor in the sensitivity analysis (0.02) is slightly different to the value in Table 4.1 which is used for the simulations shown in Figure 4.2 and 4.3.

a) Output growth



b) Persistence factor



c) Impact factor

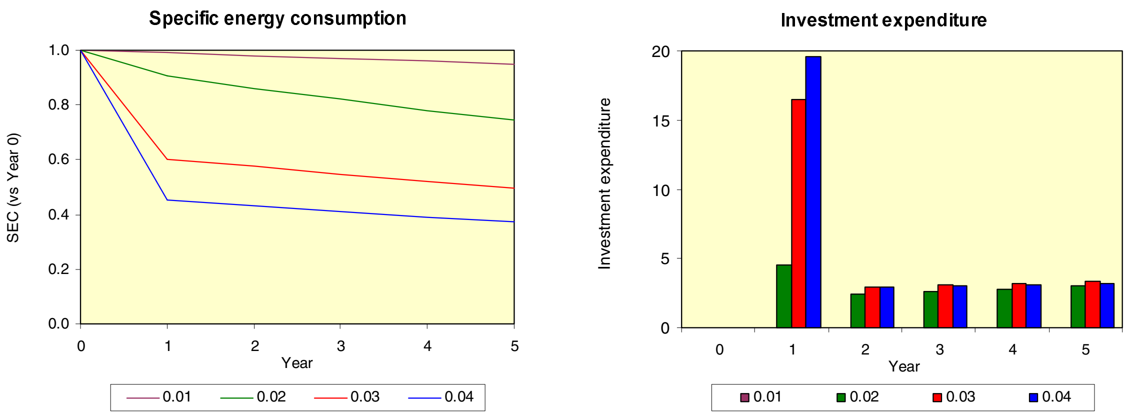


Figure 4.1: Sensitivity analysis

There are two general observations that can be made, which apply to all three parameters. First, when each parameter is set to its lowest value (with the other two at their base value), the firm does not undertake any energy efficiency expenditure and hence SEC follows the BAU trajectory. This implies that if output is declining, or if expenditures have little beneficial impact, or if the impact depreciates quickly, then it may well be optimal for the firm to do nothing to improve energy efficiency. Second, where expenditure is undertaken, the resultant SEC trajectories are (with one exception) kinked, with a relatively large decline in the first period followed by smaller reductions in the following periods. However, the impact of increasing parameter values on the extent of the kink varies between the three parameters. For output growth, expenditure becomes more even (and hence SEC less kinked) as the growth rate is increased. Indeed, when output is flat, expenditure is only undertaken in the first period. In contrast, for the persistence factor and the impact factor, expenditure becomes more skewed as the parameter values are increased; with first period expenditure increasing significantly, but little change in the following periods. The one exception to this pattern occurs when the persistence factor is set to 85%. In this case, expenditure is only undertaken in the final period and hence SEC only deviates from the BAU trajectory in that period.

Figure 4.2 shows the SEC trajectories under the six scenarios when the final tear target is binding, and when it is non-binding. As one might expect – given the parameter values used for the simulation and the insights provided by the sensitivity analysis – all of the trajectories are kinked, with significant reductions in SEC in the first year, and little improvement thereafter.

The trajectories for the unregulated cost-minimizing scenario (CMIN-U) and for the two scenarios that include trading (CMIN-R (C1) and (C2)) are exactly the same in the two cases; with SEC being lower in every period when credit prices are expected to rise in-line with the interest rate (i.e. the discounted price remain constant).

For the two scenarios that exclude trading (CMIN-R (A) and (B)), the stringency of the final-year target does affect the SEC trajectories. If the target is non-binding, then the trajectories under these two scenarios coincide with the unregulated cost-minimizing trajectory (CMIN-U). This is not the case however when the target is binding. While the trajectories coincide for the first two years if the firm uses neither if the flexibility mechanisms (CMIN-R (A)), they diverge thereafter; with SEC then being equal to the target value in each period. If the firm uses the banking mechanism (CMIN-R (B)) then SEC is lower than the corresponding unregulated cost-minimizing value in every period.

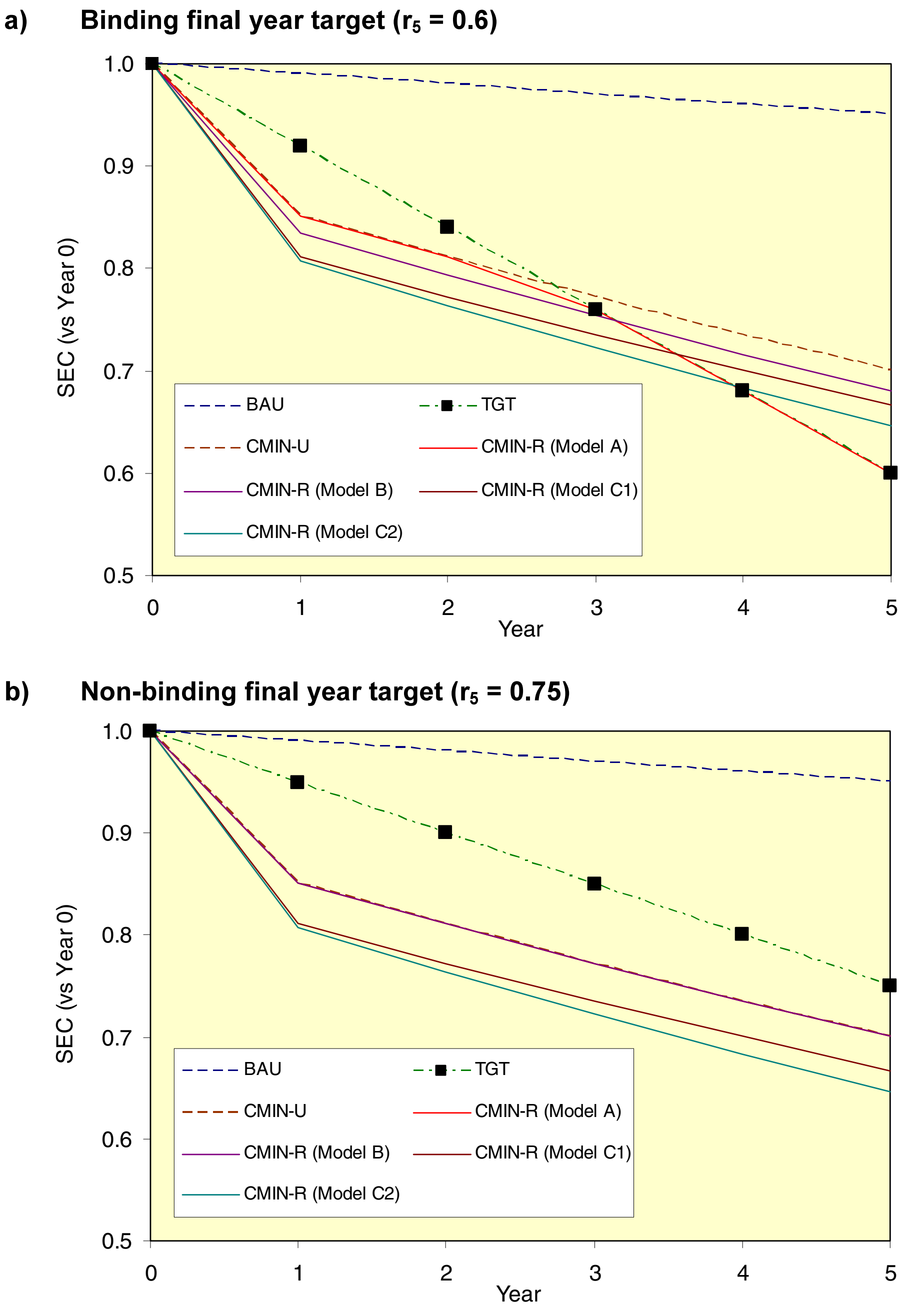


Figure 4.2 SEC trajectories

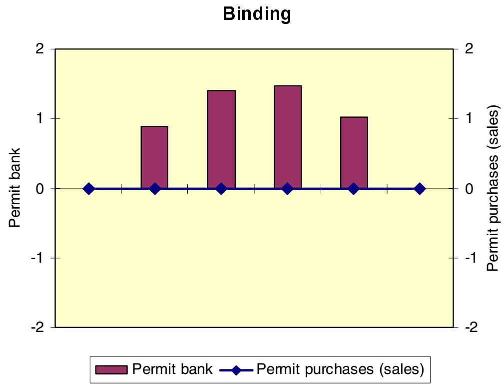
When the final-year target is non-binding, the interim targets are over-achieved in every year. In contrast, when the final-year is binding, the interim targets are only over-achieved in the earlier years. In the later years, the target is either achieved exactly (CMIN-R (A)) or under-achieved; with either banked credits being used to make up the shortfall (CMIN-R (B)), or purchased credits (CMIN-R (C1)), or either / both (CMIN-R (C2)).[34] Thus, over-achievement of interim targets in the early years provides no indication of the stringency of the final target. In this simulation, the final year target is only over-achieved if it is non-binding. However, it is possible – through judicious choice of parameter values – to generate trajectories under the full flexibility scenario (CMIN-R (C2)) with a

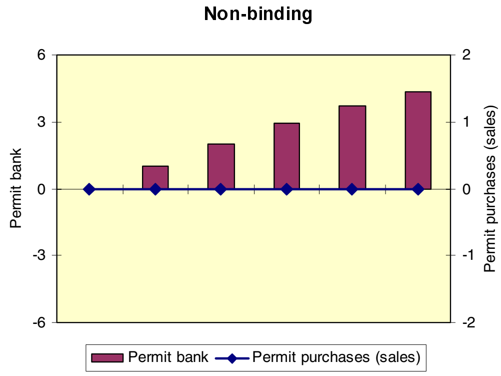
[34] As has been noted, when discounted credit prices are expected to remain constant the firm is indifferent between banking and trading credits. Consequently, it may use either banked or purchased credits to make up the shortfall.

binding final-year target, in which SEC falls below the final target value in the early years before rising again. Consequently, early over-achievement of the final-year target does not necessarily imply that it is non-binding either.

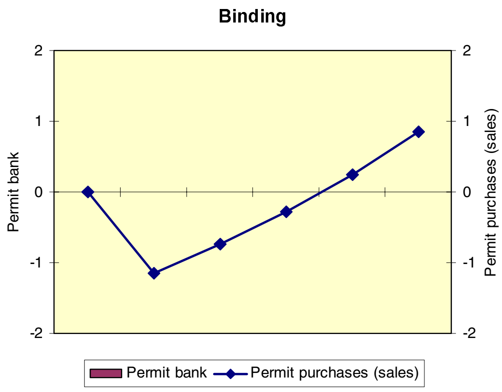
Finally, Figure 4.3 shows how the firm's behaviour – in terms of its use of the two flexibility mechanisms – is affected by the stringency of the target under the three scenarios for which these mechanisms are relevant. If the firm uses only the banking mechanism (CMIN-R (B)) then, if the final-year target is binding, it builds up the permit bank over the first three years before drawing it down to leave it empty at the end of the regulatory horizon. In contrast, when the target is non-binding, the permit bank grows continuously and has a positive value at the end of the horizon. However, it should be noted that this is not the only possible profile. Since the shadow value of the regulatory constraint (C2c) is zero, any profile in which the increase in banked credits in each period is less than that shown in Figure 4.3 will satisfy the first order conditions. In particular, it is possible for the bank to remain empty in every period (i.e. over-performance is never carried forward). If banking involves any transaction cost (financial or otherwise), then this is the more likely outcome.

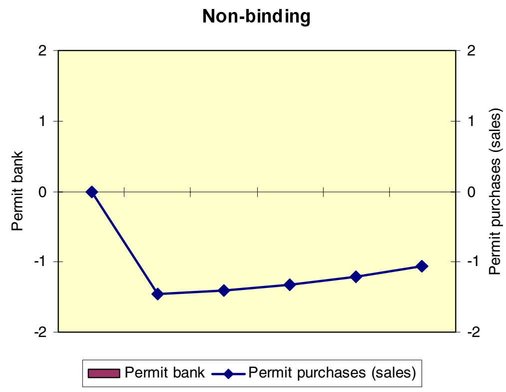
a) Scenario CMIN-R (Model B) [(a)]



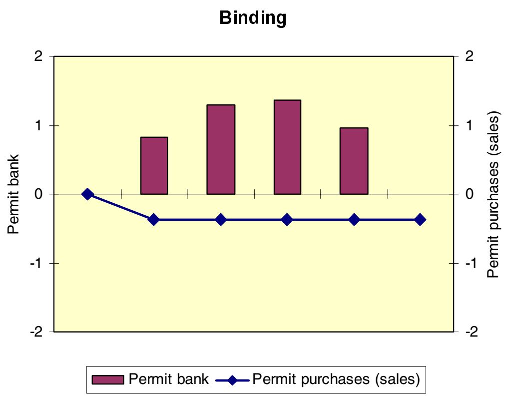


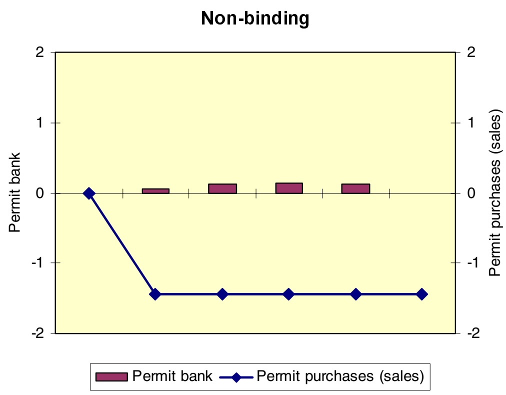
b) Scenario CMIN-R (Model C1)





c) Scenario CMIN-R (Model C2)





[(a)] Note the different scale for banked permits when the target is non-binding.

Figure 4.3: Use of flexibility mechanisms

In the other two scenarios, the firm uses trading as well as banking. As has already been noted, if it expects the price of performance credits to remain constant in nominal terms (i.e. the discounted price to decline), the firm will always sell any over-performance in the period that it occurs and purchase any credits that it needs to meet any under-performance. It will never bank any credits. Consequently, only the profile of credit transfers varies between the two cases. When the final-year target is non-binding, the firm sells credits in every year. When the target is binding, it sells credits in the first three years, but purchases them in the last two. Because the regulatory constraint is always binding when the firm uses the trading mechanism, it follows that a necessary condition for the final-year constraint to be non-binding is that:

$$\rho_T(E_T^{*})\, Y_T \quad \leq \quad L^r_T \quad = \quad \rho_T(E_T^{\#})\, Y_T \; - \; v_T^{\#}$$

Where the * superscript denotes the unregulated cost-minimizing solution and the $^{\#}$ superscript denotes the solution under the CMIN-R (C1) scenario. Rearranging yields the following inequality:

$$v_T^{\#} \leq \quad [\, \rho_T(E_T^{\#}) \; - \; \rho_T(E_T^{*})\,]\, Y_T$$

As noted above, if the firm undertakes expenditure in every period (as it does in this simulation) then $E_T^{\#} > E_T^{*}$, which means that the right-hand side of the inequality is negative. Consequently, a necessary condition for the final-year target to be non-binding is that the firm sells credits in that period. Unfortunately, this condition is not sufficient, so credit sales in the final period do not rule out the possibility that the target is binding.

If the firm expects the discounted price of credits to remain constant then it is indifferent between translating over-performance into credits and selling them immediately, or banking them and selling them in a later period. Consequently, while total net sales across the entire regulatory horizon and the final number of banked credits are both uniquely determined, the number of credits banked and / or transferred in each period is not. Thus, there are many possible combinations of trajectories.[35] The ones shown in Figure 4.3 assume that the firm chooses a banking profile so as to equalize the number of credits that it transfers in each period. In each case, the firm sells credits in every period; building up the bank over the first three years and then running it down to zero by the end of year 5. The stringency of the target only affects the relative magnitudes of the sales and the banking. When the final-year target is binding the maximum number of permits banked is relatively large, while the number sold in each year is relatively small. When it is non-binding, the opposite is true.

This is a fairly general result. As was seen in Figure 4.2, the stringency of the target has no affect on the values of the firm's expenditure levels, which are determined by the discounted credit price. Since the interim targets follow a linear trajectory[36], it follows directly that:

$$(\, B_t^{\#} - B_{t-1}^{\#}\,) \; - \; v_t^{\#} \quad > \quad (\, B_t^{\#\#} - B_{t-1}^{\#\#}) \; - \; v_t^{\#\#} \qquad \text{for all } t$$

where the $^{\#}$ superscript denotes the solution when the target is non-binding and the $^{\#\#}$ superscript denotes the solution when it is. Summing across the regulatory horizon yields the following inequality:

[35] Assuming that performance credits are denominated in integer values, the number of possible combinations is finite, but potentially very large.

[36] The assumption of a linear trajectory is not necessary. All that is required is that the interim targets are more stringent for the binding target than the non-binding target

$$\sum_{t=1}^{T}(-v_t^{\#}) \quad = \quad \sum_{t=1}^{T}\left[L_t^{r\#} - \rho(E_t^{\#})Y_t\right] \quad > \quad \sum_{t=1}^{T}\left[L_t^{r\#\#} - \rho(E_t^{\#\#})Y_t\right] \quad = \quad \sum_{t=1}^{T}(-v_t^{\#\#})$$

Hence, the firm sells more credits if the target is non-binding; which, of course, is not a very surprising result. It also follows that for any intermediate year t:

$$\sum_{t=1}^{t}(B_t^{\#} - B_{t-1}^{\#}) \overset{\sim}{.} \sum_{t=1}^{t}(B_t^{\#\#} - B_{t-1}^{\#\#}) \quad = \quad \sum_{t=1}^{t}\left[L_t^{r\#} - L_t^{r\#\#}\right] {}^{\sim} \sum_{t=1}^{t}\left[(-v^{\#}) - (-v^{\#\#})\right]$$

$$= \quad \sum_{t=1}^{t}\left[L_t^{r\#} - L_t^{r\#\#}\right] {}^{\sim} \sum_{t=1}^{T}\left[L_t^{r\#} - L_t^{r\#\#}\right]$$

$$= \quad \sum_{t=t+1}^{T}\left[L_t^{r\#\#} - L_t^{r\#}\right] \quad < \quad 0$$

where $v^{\#}$ and $v^{\#\#}$ denote the "constant sales" for the non-binding and binding targets respectively. Hence, the cumulative number of banked credits is lower in every intermediate period for the non-binding target.

4.5 Summary

A theoretical model – supplemented by a simple numerical simulation – has been used to assess whether it is possible to infer anything about the cost-efficiency of a firm's achieved SEC when it is subject to a regulation that imposes energy efficiency targets over a fixed number of years, but includes flexibility mechanisms in the form of banking and credit trading (as is the case with the Climate Change Agreements).

It is not possible to draw many conclusions about the marginal cost of energy efficiency improvements from the shape of the firm's SEC trajectory, or by comparing actual performance with the target values in the interim years. The stringency of the targets and the extent to which the firm utilizes the flexibility mechanisms appear to have little impact on the basic shape of the trajectory; which typically comprises a significant reduction in the first year followed by smaller improvements thereafter. So the shape of the trajectory provides no indication of the cost-efficiency of the improvements. Furthermore, over-achievement of the targets in the early years of the regulation does not necessarily imply that the achieved improvements are cost-efficient. Depending on its use of the flexibility mechanisms, it is quite possible that a cost-minimizing firm will choose to reduce its SEC below target, to a point where the marginal cost is positive. However, if the firm undertakes expenditure in every period, the SEC trajectory under regulation will never lie above the unregulated cost-minimizing trajectory. Consequently, if actual SEC is greater than or equal to the target value then this necessarily implies that the target is binding and hence that the marginal cost is positive.

While inspection of the SEC trajectory provides little or no information about the marginal cost of energy efficiency improvements, an understanding of the firm's use of the two flexibility mechanisms can do so. If the firm minimizes the net present value of its overall energy costs including energy efficiency investments, then the net marginal cost of improving energy efficiency (i.e. the excess of the marginal cost over the marginal benefit) is given by the shadow value of the regulatory constraint in that period. Depending on the extent to which the firm uses the flexibility mechanisms, the market price of performance credits can provide information about this value.

If the firm uses both mechanisms proactively, then the shadow value in each period is equal to the discounted price of performance credits.[37] Thus, provided that this price is strictly positive, the achieved SEC will be costly in every period, irrespective of whether it beats the respective target values, or not. However, if the firm only uses the banking mechanism, then the shadow value will depend on the level of its "credit bank" in that period and all future periods over the regulatory horizon. A necessary (but not sufficient) condition for the shadow value to be positive is that the number of banked permits falls to zero at the end of that period, or some future period. In this case, the discounted price of performance credits provides a lower bound for the marginal cost of improving energy efficiency if the firm is a "latent buyer" of performance credits in the last period in which the bank falls to zero, and an upper bound if it is a "latent seller" in the first period of the regulatory horizon. However, if the number of banked credits remains strictly positive over the remaining periods – including the final period, then the shadow value is equal to zero. Finally, if the firm uses neither of the mechanisms, all that can be inferred is that the marginal cost is zero if the actual SEC is less than the target value, and that it is greater than (or possibly equal to) zero if it coincides with the target. In this case, the discounted permit price provides no information about the marginal cost.

Thus, in order to draw any conclusions about the marginal cost of the achieved improvements in energy efficiency, it is necessary to know which, if either, of the two flexibility mechanisms is utilized by the firm. This might be known *a priori* – for example, a firm may make an announcement about this. Alternatively, it may be possible to infer which are being used from the observed trajectories for SEC, credit transfers and banking. While this cannot always provide a definitive indication – particularly in the early years, it is likely to be the only option if one is trying to determine the behaviour of a "representative firm" from aggregate data.

[37] The firm uses the mechanisms proactively if it includes them in its potential set of energy management options – i.e. as a potential alternative to taking actions itself. Alternatively, it may use the trading mechanism reactively as a "backstop"; only purchasing permits if it needs to because its actions have not delivered the expected improvements in SEC. In this case, it does not include permit transfers in its optimization problem.

Section 5: Conclusions

The potential for cost-efficient improvements in energy efficiency for the COMETR sectors in the United Kingdom has been assessed using three different – but complementary - approaches:

- A "bottom-up", technology-based simulation model (ENUSIM) has been used to assess the potential for cost-efficient reductions in SEC based on information about the costs and impacts of identified technologies, plus assumptions about economic parameters and behavioural responses.
- Actual performance data reported under the relevant Climate Change Agreements (CCAs) has been compared with "business-as-usual" counterfactuals (generated by ENUSIM) to assess the scale of the improvements in SEC that have been achieved over recent years.
- A theoretical model has been used to explore how a cost-minimizing firm might be expected to behave and to determine what information can be gleaned about the cost-efficiency of actual and target energy efficiency improvements from observed SEC performance data and the firm's use of the flexibility mechanisms allowed under the CCAs.

Taken together, the insights derived from these three exercises provide an indication of potential that existed at the end of the 1990s – prior to the introduction of the CCAs in 2001.

The simulations generated by the ENUSIM model suggest that in 1995 there was a significant potential for cost-efficient improvements in energy efficiency in all of the COMETR sectors, ranging from around 10% (for Steel, Meat Processing and Cement, Lime and Plaster) to over 20% (for Non-ferrous Metals, Chemicals and Paper). However, the shape of the cost curves generated by the model also suggests that for the majority of this potential, the financial savings were only marginal and hence much smaller improvements could also be consistent with cost-minimising behaviour.

Of course, the "validity" of these estimates depends on the extent to which the algorithms included in ENUSIM reflect the actual decision-making processes of firms and whether the assumed parameter values are realistic. In particular, the model assumes that there are no restrictions on the availability of capital or managerial resources (such as time); although to a certain extent these constraints may be reflected implicitly in the parameter values that determine the rate at which technologies are taken up. To the extent that these "hidden costs" are significant and not adequately reflected in the technology penetration curves, the potential for cost-efficient improvements will be overstated. However, the technologies included in the model are only a subset of the actual technologies and behavioural changes available to firms in practice, particularly in future years. Furthermore, the model may not adequately reflect (possibly significant) reductions in the capital costs of some technologies as they move up the penetration curve. To the extent that these factors are significant, ENUSIM will understate the potential cost-efficient improvements that can be achieved. Unfortunately it is impossible to gauge the relative importance of these factors, and hence whether the estimates generated from the model overstate, or understate, the potential for cost-efficient improvements in energy efficiency. However, given the scale of the estimates it seems reasonable to conclude that the potential was significantly greater than zero.

Turning to the performance under the CCAs; with the exception of the Meat Processing sector, there have been significant reductions in SEC versus the sectors' respective base years. In particular, the

Paper, Chemicals and Ferrous Metals sectors all achieved improvements in the order of 15%-20% over a 6-7 year period; although, in the last case this appears to have been driven by major structural changes in the sector. Compared to a business-as-usual counterfactual, the improvements are reduced somewhat, but still significant; ranging from 4% to 17%.

Again with the exception of the Meat Processing sector, these improvements have generated significant financial benefits; with reductions in energy expenditures ranging up to £235 million for the Chemicals sector. There is no evidence to suggest that the sectors have undertaken any incremental capital expenditure to achieve these reductions. Consequently, any investments that have been made specifically to improve energy efficiency must have displaced expenditure that would have been undertaken on productive plant and equipment. While the extent of any such displacement is not known, if it was less than 20% (which does not seem implausible) then the estimated energy cost savings would represent an undiscounted payback period of less than 2 years. Only for the Meat Processing sector is this not the case. For this sector, if energy efficiency investments accounted for only 1% of the total capital expenditure, the payback period would still be in excess of six years.

The significant reductions in SEC are reflected in the sectors' performance against their respective CCA targets; with all of the sectors (except Meat Processing) beating their respective targets by a considerable margin – up to six years ahead of schedule in some cases. It might be tempting to conclude from this that the achieved improvements must be cost- efficient. Unfortunately, as the theoretical model demonstrates, it is not possible to draw many conclusions about the marginal cost of energy efficiency improvements from the shape of the firm's SEC trajectory, or by comparing actual performance with the target values in the interim years. In particular, over-achievement of the targets in the early years of the regulation does not necessarily imply that the achieved improvements are cost-efficient. Depending on its use of the banking and trading mechanisms available under the regulation, it is quite possible that a cost-minimizing firm will choose to reduce its SEC below an interim target, to a point where the marginal cost is positive. However, if actual SEC is greater than or equal to the target value, this does necessarily imply that the marginal cost is positive.

While performance against interim targets provides little or no information about the marginal cost of energy efficiency improvements, an understanding of the use of the two flexibility mechanisms can do so. If the firm uses both mechanisms proactively, then the marginal cost in each period is equal to the discounted price of performance credits. Thus, provided that this price is strictly positive, the achieved SEC will be costly in every period, irrespective of whether it beats the respective target values, or not. However, if the firm only uses the banking mechanism, then the marginal cost will depend on the level of its "credit bank" in that period and all future periods over the regulatory horizon. A necessary (but not sufficient) condition for the marginal cost to be positive is that the number of banked permits falls to zero at the end of that period, or some future period. In this case, the discounted price of performance credits provides a lower bound for the marginal cost if the firm is a "latent buyer" of credits in the period in which the bank falls to zero and an upper bound if it is "latent seller" of credits in the first period of the regulatory horizon. If the number of banked credits remains strictly positive over the remaining periods – including the final period, then the marginal cost is equal to zero in every period. Finally, if the firm uses neither of the mechanisms, all that can be inferred is that the marginal cost is zero if the actual SEC is less than the target value, and that it is greater than (or possibly equal to) zero if it coincides with the target. In this last case, the discounted permit price provides no information about the marginal cost.

It had been intended to include an analysis of the actual trading and banking profiles of the COMETR sectors based on the transaction logs for UK Emissions Trading Scheme (UKETS), in order to assess the extent to which the CCA participants have used these flexibility mechanisms. Unfortunately, due to problems with the data it was not possible to do this. However, a cursory review of the aggregate data for CCA participants across all sectors suggests that while over-performance is being banked, trading is only being used retrospectively by a relatively small number of firms to meet shortfalls against their targets; with little evidence that firms are using the mechanism as a proactive "energy management option". Furthermore, given the large number of banked permits at the end of TP2 and the early achievement of future targets, it seems unlikely that the number will fall to zero by the end of the agreements in 2010. On the basis of the results of the theoretical model, this would imply that the improvements in energy efficiency were achieved at zero, or negative, cost.

Taken together, the insights provided by the three approaches suggest that there was significant potential for cost-efficient improvements in energy efficiency in all of the sectors – with the possible exception of the Meat Processing sector.

With the exception of the Ferrous Metals and Paper sectors (for which there are plausible explanations), there is a close correlation between the actual improvement in energy efficiency reported under the CCAs and the potential improvement calculated by the ENUSIM model. That is, those sectors with the greatest modelled potential for cost efficient improvements have achieved the greatest actual improvements. This lends considerable credence to the estimates of the cost-efficient improvement potentials produced by the model.

Significant improvements in energy efficiency have been achieved over a relatively short period of time; resulting in significant reductions in energy costs for most of the sectors. The relatively short timescales suggest that the improvements have been achieved without the need for major capital investment programmes. Indeed, there is no evidence of any incremental capital expenditure being undertaken in any of the sectors with the possible exception of the Ferrous Metals sector; although this is likely to reflect a catching-up of investment following a significant downturn at the end of the 1990s. Under plausible assumptions about the displacement of productive investment, the estimated reductions in energy costs imply very short payback periods. This conclusion is supported by the high levels of banking of performance credits, which – theoretically – implies that the marginal cost of improving energy efficiency has been (less than) zero.

The one exception to this general conclusion is the Meat Processing sector. For this sector, the high attrition rate of participants from the CCA; the under-performance versus the CCA target in the second target period; the minimal reductions in SEC and energy costs; and relatively long estimated payback period; all suggest that that improvements in energy efficiency have been costly for this sector.

References

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DEFRA (2002) *ENUSIM Manual*, Report by Entec UK Ltd and Cambridge Econometrics for Department for Environment, Food and Rural Affairs, Version 2, September 2002

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Annex A: Simulation results

Table A1: Sensitivity analysis – output growth

a) Specific energy consumption

Output growth	Year					
	0	1	2	3	4	5
-5%	1.000	0.990	0.980	0.970	0.961	0.951
0%	1.000	0.961	0.954	0.947	0.940	0.933
5%	1.000	0.905	0.862	0.821	0.782	0.744
10%	1.000	0.864	0.785	0.714	0.649	0.590

b) Energy efficiency expenditure

Output growth	Year					
	0	1	2	3	4	5
-5%	0.000	0.000	0.000	0.000	0.000	0.000
0%	0.000	1.490	0.000	0.000	0.000	0.000
5%	0.000	4.504	2.391	2.583	2.779	2.971
10%	0.000	6.830	4.949	5.374	5.803	6.228

NOTE:
Persistence factor = 90%
Impact factor = 0.02

Table A2: Sensitivity analysis – persistence factor

a) Specific energy consumption

Pers. factor	Year					
	0	1	2	3	4	5
80%	1.000	0.990	0.980	0.970	0.961	0.951
85%	1.000	0.990	0.980	0.970	0.961	0.921
90%	1.000	0.905	0.862	0.821	0.782	0.744
95%	1.000	0.690	0.658	0.626	0.596	0.568

b) Energy efficiency expenditure

Pers. factor	Year					
	0	1	2	3	4	5
80%	0.000	0.000	0.000	0.000	0.000	0.000
85%	0.000	0.000	0.000	0.000	0.000	1.634
90%	0.000	4.504	2.390	2.584	2.778	2.972
95%	0.000	18.019	2.840	2.937	3.034	3.133

NOTE:
Output growth = 5%
Impact factor = 0.02

Table A3: Sensitivity analysis – impact factor

a) Specific energy consumption

Impact factor	Year					
	0	1	2	3	4	5
0.01	1.000	0.990	0.980	0.970	0.961	0.951
0.02	1.000	0.905	0.862	0.821	0.782	0.744
0.03	1.000	0.603	0.574	0.547	0.521	0.496
0.04	1.000	0.452	0.431	0.410	0.391	0.372

b) Energy efficiency expenditure

Impact factor	Year					
	0	1	2	3	4	5
0.01	0.000	0.000	0.000	0.000	0.000	0.000
0.02	0.000	4.504	2.390	2.584	2.778	2.972
0.03	0.000	16.518	2.945	3.074	3.203	3.333
0.04	0.000	19.581	2.928	3.024	3.123	3.218

NOTE:
Output growth = 5%
Persistence factor = 90%

Table A4: Binding final year target

a) Energy consumption (z_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	10.000	10.396	10.807	11.234	11.678	12.140
CMIN-U	10.000	8.941	8.941	8.941	8.941	8.941
CMIN-R (A)	10.000	8.941	8.941	8.798	8.265	7.658
CMIN-R (B)	10.000	8.770	8.751	8.731	8.708	8.683
CMIN-R (C1)	10.000	8.515	8.515	8.515	8.515	8.515
CMIN-R (C2)	10.000	8.471	8.421	8.367	8.308	8.243

b) Energy efficiency expenditure (e_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-U	0.000	7.092	2.535	2.717	2.900	3.082
CMIN-R (A)	0.000	7.092	2.535	3.477	5.914	7.046
CMIN-R (B)	0.000	8.003	2.726	2.929	3.135	3.343
CMIN-R (C1)	0.000	9.388	2.764	2.947	3.130	3.312
CMIN-R (C2)	0.000	9.636	3.064	3.302	3.547	3.797

c) Energy efficiency capital (E_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-U	0.000	7.092	8.918	10.743	12.568	14.394
CMIN-R (A)	0.000	7.092	8.918	11.503	16.266	21.686
CMIN-R (B)	0.000	8.003	9.928	11.865	13.813	15.775
CMIN-R (C1)	0.000	9.388	11.214	13.039	14.865	16.690
CMIN-R (C2)	0.000	9.636	11.736	13.865	16.025	18.219

d) Permit bank (B_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-U	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (A)	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (B)	0.000	0.890	1.400	1.467	1.025	0.000
CMIN-R (C1)	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (C2)	0.000	0.823	1.296	1.361	0.952	0.000

e) Permit transfers (v_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-U	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (A)	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (B)	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (C1)	0.000	-1.145	-0.746	-0.283	0.250	0.858
CMIN-R (C2)	0.000	-0.366	-0.366	-0.366	-0.366	-0.366

f) Specific energy consumption (ρ_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	1.000	0.990	0.980	0.970	0.961	0.951
CMIN-U	1.000	0.852	0.811	0.772	0.736	0.701
CMIN-R (A)	1.000	0.852	0.811	0.760	0.680	0.600
CMIN-R (B)	1.000	0.835	0.794	0.754	0.716	0.680
CMIN-R (C1)	1.000	0.811	0.772	0.736	0.701	0.667
CMIN-R (C2)	1.000	0.807	0.764	0.723	0.684	0.646

Table A5: Non-binding final year target

a) Energy consumption (z_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	10.000	10.396	10.807	11.234	11.678	12.140
CMIN-U	10.000	8.941	8.941	8.941	8.941	8.941
CMIN-R (A)	10.000	8.941	8.941	8.941	8.941	8.941
CMIN-R (B)	10.000	8.941	8.941	8.941	8.941	8.941
CMIN-R (C1)	10.000	8.515	8.515	8.515	8.515	8.515
CMIN-R (C2)	10.000	8.471	8.421	8.367	8.308	8.243

b) Energy efficiency expenditure (e_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-U	0.000	7.092	2.535	2.717	2.900	3.082
CMIN-R (A)	0.000	7.092	2.535	2.718	2.899	3.083
CMIN-R (B)	0.000	7.092	2.535	2.718	2.899	3.083
CMIN-R (C1)	0.000	9.388	2.764	2.946	3.130	3.311
CMIN-R (C2)	0.000	9.637	3.064	3.302	3.547	3.797

c) Energy efficiency capital (E_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-U	0.000	7.092	8.918	10.743	12.568	14.394
CMIN-R (A)	0.000	7.092	8.917	10.743	12.568	14.393
CMIN-R (B)	0.000	7.092	8.917	10.743	12.568	14.393
CMIN-R (C1)	0.000	9.388	11.214	13.038	14.865	16.690
CMIN-R (C2)	0.000	9.637	11.736	13.864	16.025	18.219

d) Permit bank (B_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-U	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (A)	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (B)	0.000	1.034	2.015	2.914	3.697	4.328
CMIN-R (C1)	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (C2)	0.000	0.060	0.116	0.144	0.116	0.000

e) Permit transfers (v_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-U	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (A)	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (B)	0.000	0.000	0.000	0.000	0.000	0.000
CMIN-R (C1)	0.000	-1.460	-1.407	-1.324	-1.209	-1.057
CMIN-R (C2)	0.000	-1.445	-1.445	-1.445	-1.445	-1.445

f) Specific energy consumption (ρ_t)

Scenario	Year					
	0	1	2	3	4	5
BAU	1.000	0.990	0.980	0.970	0.961	0.951
CMIN-U	1.000	0.852	0.811	0.772	0.736	0.701
CMIN-R (A)	1.000	0.852	0.811	0.772	0.736	0.701
CMIN-R (B)	1.000	0.852	0.811	0.772	0.736	0.701
CMIN-R (C1)	1.000	0.811	0.772	0.736	0.701	0.667
CMIN-R (C2)	1.000	0.807	0.764	0.723	0.684	0.646

The Effects of Environmental Tax Reform on International Competitiveness in the European Union: modelling with E3ME

WP4

Terry Barker, Sudhir Junankar, Hector Pollitt & Philip Summerton, Cambridge Econometrics

connecting you to the future

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Executive Summary

Objectives

- The objective of Work Package 4 is to evaluate the short and long term economic effects of environmental tax reforms (ETRs) in the European Union (EU) in the macroeconomic framework provided by CE's Energy-Environment-Economy model for Europe, E3ME. The analysis undertaken in this work package focussed upon the competitiveness effects in the COMETR sectors[1] for the six[2] countries that undertook environmental tax reform in the 1990s: Denmark, Finland, Germany, the Netherlands, Sweden and the UK. (For Slovenia, the CO2 tax, although not strictly part of an ETR, has been included in the Baseline scenario to give an example of environmental taxation in the New Member States). The modelling sought to capture the inter-industry and other indirect effects, as well as international competitiveness effects, which cannot be well accounted using the bottom-up approach used in Work Packages 2 (Market) and 3 (Bottom up). The ultimate goal is to compare the short and long-term effects of ETR (on economic activity in most cases).

- The main emphasis of the work has been on measuring the direct (and indirect) price and non-price competitiveness effects of ETR and on examining the dynamic impact on external trade, employment, output, investment in capital and R&D in the various ETR scenarios. These results have fed into WP5. The analysis has been carried out for each ETR Member State considered in the bottom-up case studies and for all the non-ETR EU countries together**.** The change in the sectors' costs due to a change of input composition and prices leads to a different position of the sectors in the international markets. So particular emphasis of the work has been on the modelling of effects of the green-tax reform on external position of the sectors and any implication it has for the single market and enlargement.

- The results of the modelling undertaken in WP4 serve two purposes
  - to identify the key characteristics of the green tax reform packages, compared with a 'Reference case' (ie a counterfactual case) generated by E3ME over the period 1994-2012 without ETR, but including current and expected developments in the EU economy, eg the impact of the EU ETS. The wider competitiveness effects of the reform on other sectors and through international trade were assessed through the comparison of the effects 1994 to 2012.
  - to give signals to policy makers about the relative effectiveness of different policy instruments (eg the full tax or levy, compared with the tax with exemptions and/or special treatment for affected sectors and including and excluding revenue recycling) for overcoming the short-term costs of policies with possible beneficial long-term effects on competitiveness as suggested by the Porter hypothesis

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[1] The five parent NACE 2 E3ME sectors were: 15: Food and food products; 21: Pulp, paper and paper products,; 24: Chemical and chemical products; 26: Non-metallic mineral products; and 27: Basic metals.

[2] Six EU member states undertook ETRs; Denmark, Germany, the Netherlands, Finland, Sweden and the UK. Slovenia has also been included in the baseline as an example of a new member state which introduced a carbon-energy tax but did not implement a full ETR.

Purpose of ETRs

- The purpose of an ETR is to shift taxation away from beneficial activities, such as employment, towards damaging activities such as pollution. The idea is to implement specific taxes to encourage households and industries to behave in a way which is environmentally sustainable. The revenues thereby generated can be used to reduce burdensome taxes or increase benefits or investment in energy-saving programmes. All the taxes are assumed to be revenue neutral, meaning that the revenues from the energy taxes are exactly balanced by 'revenue recycling' schemes. This recycling mechanism may take effect through:
  - Direct taxes (income tax, corporation tax);
  - Social security contributions (ie paid by employers or paid by employees).
  - Other measures (eg support schemes for investment expenditure, and depreciation; and benefits or other compensatory measures) that may, however, reduce the scope for reducing other taxes.

Macro-economic modelling of international competitiveness and carbon leakage

- Carbon leakage is measured by the increase in CO2 emissions outside the countries taking domestic mitigation action divided by the absolute reduction in the emissions of these countries. The main empirical findings from a literature review, discussed in Chapter 2, are as follows: much of the literature is on the leakage from Kyoto action, but it is based on stylised and rigid assumptions, which occasionally give extreme and unconvincing results. For the purpose of investigating carbon leakage within the EU, there is not enough literature to warrant conclusions about the effects of climate change policies of one Member State on emissions elsewhere in the EU. The same arguments apply as to those between Annex I and non-Annex I countries in a global context, but technological transfer within the EU is likely to be easier, and the cross-border activities of multinationals are more extensive. Barker (1998) provides estimates of leakage from unilateral policy action by EU Member States for a 10% reduction in GHGs by 2010. The results show that leakage can go both ways, but the estimates are very small in relation to the effects in the countries taking action (see Chapter 2, Table 2.1).

Specification of the scenarios

- The 'Reference Case' which is a counterfactual projection without the ETR (*R for "Reference"*), but including current and expected developments in the EU economy, eg the EU ETS;
- The 'Baseline Case' which is an endogenous solution of E3ME (*B for "Baseline"*) over the period 1994-2012. This scenario includes the ETR in each Member State to be covered by the project, exemptions or special treatment for the industries most affected and the compensating reduction in another tax. This scenario is calibrated closely to the observed outcome through using historical data, which includes the effects of ETR implementation (the historical part of the Baseline);
- The tax with no exemptions and special treatment but with compensating measures (*E for "tax with no exemption"*);
- The case with a compensating reduction in another tax on its own (*C for "compensation"*). Usually, a scenario of this type would look at the effects of the taxes without the revenue recycling. Here it is done the other way round because the ETRs are subtracted from the baseline rather than added. This scenario therefore subtracts the energy and carbon taxes (so there is no ETR) from the baseline but does not change the compensating measure from the baseline (so we do have revenue recycling as in the baseline). To do the opposite (a scenario with

the energy and carbon taxes but not the compensating measures) would be difficult as, without changing the energy and carbon taxes it is not obvious how large the compensating measure should be. By comparing scenario C to the baseline we can isolate the effects of the energy and carbon taxes. By comparing scenario C to the reference case we are isolating the effects of the compensating measures;

- These scenarios allow the ETR to be decomposed country by country into three components: the full tax, the exemptions, the compensation via recycling. The detailed results of the four main scenarios are analysed in the work package at the sectoral level (for the specified COMETR sectors and countries) and at the macro-economic level are presented in Appendix E. The direct (and indirect) price and non-price competitiveness effects of ETRs are briefly considered to see whether any inferences can be drawn in relation to the Porter hypothesis (ie, "improved performance in the ETR sectors will level out the impact of the increased tax level", see p4-5 of COMETR Annex I – Description of the work).
- The ETR scenarios are also analysed sector by sector to consider the impact of the ETRs on competitiveness by the energy-intensive sectors, which are the focus of the study. The results of the above scenarios are then used to evaluate the sector impact of industrial-specific taxes, exemptions and/or special treatments on other industries and the economy as a whole. By calculating the overall size of tax shifts (eg, in percentage of GDP) paid by/recycled to industry and households, the net 'winners' and 'losers' of the ETRs can be identified. The aggregate of the individual industry-specific impacts is equivalent to the effects in the Baseline Case scenario in relation to the Reference Case.

- The Baseline case is an endogenous model solution of E3ME solved annually over the period 1994-2012. The historical part of the Baseline solution, used for the *ex-post* analysis of the period 1994-2002 (or 2003 where data were available at the start of the project in November 2004) are taken from E3ME's historical databanks, constructed from historical data from Eurostat, the OECD and the IEA. These data include the effects of ETRs in the 1990s and any accompanying exemptions and revenue recycling methods. The forecast part of the Baseline solution, used for *ex-ante* analysis, is derived from DG TREN's 2003 'European energy and transport: Trends to 2030' (used by the EEA for its 2005 Outlook) and the IEA's energy price projections. Although the DG TREN forecast provided a consistent set of projections for energy demand and economic activity, some of the key assumptions (ie energy prices, world growth and the EU ETS) underlying the forecast were no longer up to date. To compensate for this, E3ME was calibrated to meet the DG TREN forecast and then solved again with a different set of assumptions for energy prices that took account of the 2004-05 oil price rise and the introduction of the EU ETS. The assumptions for energy prices are important to the analysis, because they set the ratio of environmental taxes to total fuel cost (ie the difference between the scenarios) which determines the scale of the effects. However it was not possible to obtain more recent forecasts of world economic growth that were consistent with other inputs and so the DG TREN projections were used.

- ETR is defined as the environmental tax reforms that took place during the 1990s. Existing taxes and excise duties are not considered to be part of the ETR. Tax reforms that were not for environmental reasons, such as those to maintain strategic stockpiles of fuel, are not considered to be part of the ETR. All taxes were converted into consistent tax rates (euros/tonne of oil equivalent) and revenues (euros).

- The effects of the ETRs discussed below are derived from a comparison of the results for the Baseline and Reference cases and shows the difference between what happened and what would have happened in the absence of ETR (with both cases projected to 2012). The exception to this is that revenue neutrality is assumed in each case through revenue recycling mechanisms (see Chapter 3). Exemptions, non-payments, and negotiated agreements are included as accurately as possible, subject to the total revenues matching the published data in each instance. The data used for this analysis are therefore the tax *revenues* collected by the COMETR partners and the *effective* tax rates are determined by the ratio of revenues to fuel use. In the UK case, the effective tax rates were calculated similarly with the revenues from the Climate Change Levy being divided up according to fuel use. This treatment implicitly takes into account the fact that the sectors with Climate Change Agreements are paying the lower rate on the assumption that the energy efficiency targets were met.

- All the ETRs were assumed to be revenue neutral so that the effect of a shift in taxation rather than a change in the overall tax burden could be examined. In Germany and the UK, revenue recycling mainly took place through reductions in social security contributions by employers and employees. Of the six countries examined, a variety of methods were used to recycle the tax revenues and, in some cases, a combination of methods was used (see Chapter 3 for details). For several countries no explicit revenue recycling mechanisms were implemented, either because the ETRs were part of a such a wide package that it was impossible to determine what the alternative tax arrangements would be, or simply because no provisions were put in place at the time. In these countries it is assumed that income taxes were reduced to achieve revenue neutrality. This was in, our judgement, the least controversial way of maintaining revenue neutrality, as the ETR revenues are very small when compared with the overall level of income tax revenues.

Estimated competitiveness effects of ETRs: E3ME modelling results

- E3ME was extended to include the 10 countries that became members of the European Union in 2005. New data were gathered and a complete new set of equations was estimated for the entire EU-25.

- To cope with the shorter time series of available data for the New Member States, a shrinkage estimation technique, discussed in Appendix C, was developed and used to estimate the long-term parameters in these regions.

- The parameter estimates, discussed in Appendix B, determine the behavioural relationships within E3ME and can give an early indication of the scenario results.

- Non-price competitiveness is modelled through E3ME's technical progress indicators, which provide a measure of product quality. Both price and non-price competitiveness effects were found to be very important in the trade equations, particularly when considering trade within the European single market.

Key results

- The main features of the Baseline solution, discussed above, provide the background to the key findings on the overall effects of ETR, when compared with the counterfactual Reference case in the six countries, on energy demand, fuel prices, greenhouse gas emissions (GHGs), and on aggregate macroeconomic variables, including GDP, and consumer spending.

- The ETRs caused a reduction in fuel use in all six of the examined countries. The size of the reduction in fuel demand is dependent on both the tax rates imposed, how they are applied to the various fuels and fuel user groups, how easy it is for fuel users to substitute between the various fuel types and non-fuel inputs and the scale of the secondary effects from resulting changes in economic activity. All six countries show a reduction in fuel demand from ETR. In most cases, the reduction in fuel demand was around 4%, although it was slightly larger in Finland than in the other ETR countries. A key feature of the results is the recovery in fuel demand in several of the examined countries over 2004-05 in the Baseline case relative to the Reference case, due to higher world energy prices, included in both the Baseline and Reference cases. In most of the ETRs, the environmental taxes were not raised in line with fuel prices (and in some cases may have been reduced), implying a reduction in the relative change in fuel prices. The average reduction in fuel demand across the six ETR countries examined was 2.6% in 2004 and the average reduction in greenhouse gas emissions was 3.1% in 2004 (note that this includes the non-price effects assumed for commerce in the UK). The largest fall in fuel use was in Finland (4.8%) which also had the largest fall in emissions (5.9%).

- The scenario results show a reduction in greenhouse gas emissions (GHGs) in all six ETR countries arising from the ETR. The effects follow, as expected, closely the results for total fuel consumption, although the impact on GHGs will also depend upon the relative consumption levels for each fuel type. The largest reductions in emissions occur in the countries with the highest tax rates. Finland and Sweden, for example, experience the largest reductions in emissions, in most cases exceeding the decline in fuel demand, providing evidence for the efficiency of ETRs in reducing emissions. In contrast, the German ETR was not particularly efficient because it did not include coal. For the EU25, GHGs are 1.3% below baseline by 2012 as a result of the ETRs analysed in this report.

- Taxes as a share of total fuel costs fell after 2000 as energy prices rose. For example, ETR caused a 10% increase in petrol prices in Denmark in 2002 but less than 5% increase in 2005. If the ETR countries had increased taxes in line with energy costs the reduction in emissions would undoubtedly have been larger, but this is outside the defined COMETR scenarios.

- Revenue recycling meant that the cost of ETR to the economy is significantly reduced and can be expected to result in an increase in GDP. The macroeconomic impacts vary from country to country, depending on how the revenues from environmental taxes are recycled. The gains may not, however, be immediate, as there are likely to be transition costs. For all six of the examined countries the ETRs led to an increase in economic activity. In Sweden, the positive effects on GDP take longer to come through, as the very large rise in household electricity taxes depresses real incomes in the short run. Finland, in contrast, experiences a short-term boost to GDP from the effects of taxes on fuel demand, because the reduction in demand for imported fuel improves the country's trade balance. The tax shift due to the ETRs is relatively small, accounting for at most 1.25% of GDP in any ETR country (Finland in 2004).

- The scale of the longer-term economic impacts (ie the difference between the Baseline and Reference case is small but nevertheless significant, with GDP increasing by between 0.1% and 0.5% in each region, and about 0.1% for the EU25 total, up to 2012. This is largely because the tax increases were often small compared to total energy costs (particularly over 2004-05), energy accounts for a small share of total inputs even in energy intensive sectors, firms in some sectors may be able to substitute cheaper energy inputs, and the energy-intensive sectors tend to be competitive, meaning that not all of the price increase may be passed on to consumers.

- ETR caused employment in some of the ETR countries to increase by as much as 0.5%. Employment increases because the revenue from the ETR is used to reduce employers' social security contributions, therefore wage costs are reduced, and hence firms are able to increase their labour force. This is the case for Denmark, Germany, with increases of 0.5% and 0.2% respectively, in the base compared with the reference case. However, in the UK the change in employment is small; this is because the revenue recycled to reduce social security contributions was much smaller. In Sweden, employment is slightly higher due to ETR despite the use of revenues to cut income tax and not social security contributions. This is because the increase in GDP (rather than the reduction in relative labour costs) as a result of ETR causes employment to be higher than in the reference case.

- As ETRs result in higher fuel prices, there is likely to be an increase in the overall price level. The effect on prices, however, will depend on several factors, including the scale of increase in fuel costs, the ease with which industry and consumers can switch to cheaper alternatives (and non-energy inputs), how much of the cost increase is passed on to consumers (which in turn will depend on the level of competition) and the revenue recycling methods used. In the UK and Denmark there were no significant increases in the overall price index: in the former this was because the tax was relatively small and was compensated by slightly lower labour costs; in the latter the tax was larger, but was again compensated with lower labour costs. In Slovenia there was little effect. The largest inflationary effects from ETRs were in the Netherlands and, in particular, in Sweden. This reflects the fact that the measure of inflation used, the consumer price index (CPI), will record a larger increase in cases where the taxes are levied on households rather than industry for technical reasons discussed in Chapter 7. In the case of Germany, however, the revenue recycling associated with the ETR (ie reductions in employers' social security contributions reflected in lower labour costs) has a depressing effect on prices, because the ETR revenues were used to reduce employers' contributions and this outweighs the inflationary effect of the ETRs (see discussion in Chapter 7.2).

- The ETRs may also be expected to have an impact on non-ETR countries. However, the aggregate GDP effects of the 1990s ETRs are dominated by the results for Germany and it is not surprising that the there is little overall effect in Europe before the implementation of the German tax reforms in 1999. The results show that the GDP effects in other non-ETR countries are dominated by their trade patterns with Germany, but the overall scale of the difference is very small: an increase in GDP of 0.3% in the ETR countries is equivalent to about a half of one quarter's growth, while an increase of 0.05% in the non-ETR countries is six times smaller again.

- Of the six examined sectors, non-metallic mineral products and basic metals have the largest share of energy inputs. These sectors face the highest increase in costs, pushing up prices or squeezing profit margins, depending on how far product prices are set in world markets or by producers. Thus they typically have the most loss of output from the tax reforms.

- Both energy-intensive and energy-extensive sectors benefit from the revenue recycling, either through greater domestic demand (via reductions in direct taxes) or lower wage costs (via lower employers' contributions). GDP increased in every region that implemented ETR (including revenue recycling) and, although the change was typically not as much as in other sectors, output did increase in many of the energy-intensive sectors as a result of the full ETR.

- The exemptions offered to certain fuel user groups diluted the effects of the ETRs and reduced their impact. The effects are generally linear in that the higher tax rates cause a larger decrease in fuel use and emissions and this has impacts through to the wider economy. The effects of exemptions, however, are usually quite small, although it has not always proved easy in practice to define the exemptions on the environmental taxes and some simplifying assumptions have had to be made in our scenario analysis (see discussion in Chapter 7.12). The largest effect from exemptions is in the Netherlands, because the tiered electricity and gas rates to business are assumed, de facto, to be exemptions. When these are removed in scenario E, industry pays the highest tax rates and the consequent effects on fuel demand are much greater when compared with the Reference case. In comparison, there is little difference in Sweden. (As separate data for tax rates and revenues were not available for Slovenia, it was not possible to identity the effect of exemptions.)

- It is important to check the robustness of the modelling results to changes in key inputs, particularly energy prices, as the scenarios focus on the changing patterns of energy use. This is particularly vital as the results reported in Chapter 7 show that the influence of ETRs was reduced as world energy prices rose over 2004-05 and it cannot be presumed that the effects at other times would be less. To test the sensitivity of the results to changes in energy prices an additional two sets of model simulations (for Baseline and Reference cases) was created involving a 10% variation around the original assumptions. The results of this simple sensitivity show that, as expected, the impact of energy taxes is higher against a low energy price background in the two countries, Finland and Sweden, with the largest effects. The difference in the reduction in fuel demand ranges from zero to around 0.25pp in 2012 between the high and low energy price versions of the scenarios. The main result reported in Chapter 7 lies halfway in between the two energy price variants. This suggests that up to 2% of the reported difference could be due to a 10% change in the energy (oil) price in either direction. There is virtually no difference, however, in the largest ETR countries, the UK and Germany, where the ETRs were smaller in scale.

- The Porter hypothesis suggests that environmental regulation can induce efficiency and innovation and improve competitiveness as efficiency gains partially, or more than fully, offset the costs of complying with the regulation. In the COMETR context, and in Work Package 4, environmental regulation has been more narrowly defined, however, as energy taxation implemented to encourage households and industries to behave in an environmentally-sustainable manner. On this definition, our results show, in contrast, that in the absence of revenue recycling mechanisms, ETR leads to a net loss of output in all examined countries (except Finland). However, when there is revenue recycling, ETR, as modelled within E3ME, produces a small 'double dividend' effect in every country, with GDP increasing by up to 0.5% compared to the Reference case.

1 Introduction

Objectives

The objective of Work Package 4 is to use the macroeconomic framework provided by CE's Energy-Environment-Economy model for Europe, E3ME in order to evaluate the short and long-term economic effects of environmental tax reforms (ETRs) in the European Union (EU). The analysis undertaken in this work package is aimed at capturing inter-industry and other indirect effects, as well as international competitiveness effects, which cannot be well accounted for by using the bottom-up approach used in Work Packages 2 (Market) and 3 (Bottom up). The ultimate goal is to compare the short and long-term effects of ETR (on economic activity in most cases).

The main emphasis of the work has been on price and non-price competitiveness issues and the dynamics of external trade, employment, output and investment in capital that were examined in the various ETR scenarios. These results feed into Work Package 5. The analysis has been carried out for each Member State considered in the bottom-up case studies and for all the non-ETR EU countries together. The change in the sectors' costs due to a change of input composition leads to a different position of the sectors in the international markets. So particular emphasis of the work has been on the modelling of effects of the green-tax reform on external position of the sectors and any implication it has for the single market and enlargement.

The results of the modelling undertaken in WP4 serve two purposes:

- to identify the key characteristics of the green tax reform packages, compared with a 'Reference case' (ie a counterfactual case) generated by E3ME over the period 1994-2012 without ETR, but including current and expected developments in the EU economy, eg the impact of the EU ETS. The wider competitiveness effects of the reform on other sectors and through international trade were assessed through the comparison of the effects 1994 to 2012.
- to give signals to policy makers about the relative effectiveness of different policy instruments (eg the full tax or levy, compared with the tax with exemptions and/or special treatment for affected sectors and including and excluding revenue recycling) for overcoming the short-term costs of policies with possible beneficial long-term effects on competitiveness as suggested by the Porter hypothesis.

From the long-run perspective, it is necessary to model effects of the reform on dynamics of technological change and investment. These issues are addressed in the context of what the analysis undertaken in Work Package 4 suggests in relation to the so-called "Porter hypothesis". Porter's hypothesis is that environmental policy (especially green tax reform) can increase the international competitiveness of domestic industries in the long run, since the firms are forced to adopt new, energy-savings technologies as a response to increase of the energy prices. The underlying assumption is that that the new environmentally friendly technologies lead to a decrease of unit costs in the long-run perspective. However even if Porter's hypothesis holds, there may be significant short-term transition costs, which the policymakers may be able to reduce eg using tax refunds or supporting 'green' R&D policies.

1.1 Features of ETRs

The environmental tax programmes differ across the six EU-25 member states who have implemented ETRs through the industries targeted and the revenue recycling mechanisms. The green tax reform changes not only tax rates, but because of change in input demands, it changes also tax base. The effects of the green tax reforms on tax base are short and long-term: the short-term effect comes from immediate change of the composition of input costs.

The green tax reform can affect one or more of the following economic sectors: power generation, industry, households and transport. The taxes that increase under an ETR usually include energy taxes and other environmental taxes. Some ETRs may also involve the creation of a new tax that replaces an old one (that may not necessarily have the same tax base).

The purpose of an ETR is to shift taxation away from beneficial activities, such as employment, towards damaging activities such as pollution. The idea is to implement specific taxes to encourage households and industries to behave in a way which is environmentally sustainable. The revenues thereby generated are used to reduce burdensome taxes to complete the ETR.

This ‘recycling mechanism’ may take effect through:

- Direct taxes on labour (income tax, corporation tax);
- Social security contributions
    - paid by employers;
    - paid by employees;
- Other measures
    - Support schemes for investment expenditure (and depreciation) and
    - Benefits or other compensatory measures.

In certain European countries, the ETR has also included tax provisions tailored towards certain industry sectors (particularly those which are energy-intensive) to induce a more energy-efficient consumption profile and thus reduce the environmental impacts of their economic activities.

An ETR can, in principle, provide complete tax exemptions for economic sectors or reduced tax rates for different energy fuels and economic sectors in combination with some form of negotiated agreements with targets to improve energy efficiency or carbon emissions. Tax ceilings may also be established to limit the total tax burden faced by individual companies.

1.2 Outline of Report

This draft report follows the programme of work for Work Package 4, as laid out in the ‘Description of Work’ of the COMETR proposal (FP6 prop 501993, Annex 1) Chapter 2 provides details of a literature review of the research undertaken on the macroeconomic modelling of competitiveness and carbon leakage. Chapter 3 discusses the modelling undertaken in CE’s Energy-Environment-Economy Model for Europe, E3ME version 4.1 and focuses on the modelling of non-price and price competitiveness. Chapter 4 outlines the tax input data and data processing required by

E3ME, while Chapter 5 describes the ETR scenarios that were specified to examine the competitiveness effects in the COMETR sectors for the six countries that undertook environmental tax reform in the 1990s: Denmark, Germany, the Netherlands, Finland, Sweden and the UK (In Slovenia, the CO2 tax, although not strictly part of an ETR, has been included in the Baseline scenario as an example of environmental taxation in the New Member States'). Chapter 6 reviews the results of the estimation routines in E3ME relevant to measuring the direct (and indirect) price and non-price competitiveness effects of ETRs, and also outlines the econometric theory underlying the analysis, and gives some interpretation of the results. The results are analysed in Chapter 7: the construction and methodology underpinning the construction of a Baseline case scenario to 2012 are discussed first; this is followed by a detailed analysis of the key features of the macroeconomic and environmental projections in the ETR Baseline scenario and also of the implications for selected industries, at the NACE 2-digit level, that are analysed at NACE 3-digit level in Work Packages 2 and 3. We also draw out the key findings of the analysis and consider what light is cast on the validity of the so-called 'Porter hypothesis' and the implications, within the E3ME framework, for the analysis of carbon leakage due to ETRs that has formed the basis of the research in Work Package 5.

Appendix A presents the summary tables of the key parameter sets from the E3ME estimation, while Appendix B gives details of the estimation results in E3ME relevant to measuring the direct price and non-price competitiveness effects of ETRs and also their indirect effects. Appendix C presents the research conducted on incorporating the new member economies in a multisectoral, multi-regional dynamic model: applying shrinkage estimation techniques to E3ME. Appendix D shows the full set of tables for the tax rates, revenues and revenue recycling methods that were adopted in the E3ME modelling. Appendix E provides the detailed results for the ETR countries of the scenarios at the sectoral level (for the examined sectors and countries) and at the macro level.

2 Macroeconomic modelling of international competitiveness and carbon leakage

2.1 Review of the Literature on Modelling International Spillovers

Spillover effects of mitigation in a cross-sectoral perspective are taken to be the effects of mitigation policies and measures in one country or group of countries on sectors in other countries. These spillovers include effects on competitiveness of nations and sectors and 'carbon leakage'. In the literature, there has been a particular emphasis on the spillover effects of mitigation polices taken by Annex I countries on the rest of the world. In this review, the effects are divided into price and non-price effects: the price effects in turn are those on international competitiveness and overall CO_2 emissions (carbon leakage); the non-price effects are discussed as technological spillovers.

In general, the analysis of spillovers is important in the evaluation of environmental policies for economies globally linked through trade, foreign direct investment, technology transfer and information. While much of the literature recognises the existence of spillovers, different models produce different conclusions with varying level of uncertainties, with an added complication that the effects may be displaced over time. The measurement of the effects is made more difficult because they are often indirect and secondary, although they can also accumulate to make local or regional mitigation action either ineffective or the source of global transformation.

Grubb et al. (2002) argue that spillovers from Annex I action, via induced technological change, could have substantial effects on sustainable development, with emissions intensities of developing countries at a fraction of what they would be otherwise. 'However, no global models yet exist that could credibly quantify directly the process of global diffusion of induced technological change.' (Grubb et al. 2002, p. 302).

It is important to emphasize the uncertainties in estimating spillover effects. In the modelling of spillovers through international trade, researchers rely on approaches (eg bottom-up or top-down), assumptions of perfectly homogeneous versus differentiated products, and estimates (eg of substitution parameters) whose signs and magnitudes are disputed. Many of these models focus on substitution effects in estimating costs and do not consider the induced development and diffusion of technologies, as well as information, policy and political changes brought about by the originating mitigation actions.

2.2 International Competitiveness

This section covers the modelling of effects of price competitiveness, while the modelling of technological spillover effects is discussed later.

The international competitiveness of economies and sectors is affected by mitigation actions (see surveys by Boltho (1996), Adams (1997) and Barker and Köhler (1998)). In the long run, exchange rates change to compensate for persistent loss of national competitiveness, but this is a general effect and particular sectors can lose or gain competitiveness. In the short run, higher costs of fossil fuels lead to a loss in sectoral price competitiveness especially in energy-intensive industries.

The effects of domestic mitigation actions on a region's international competitiveness are divided in the literature into the effects on price and non-price competitiveness. On the issue of re-location of industry, Sijm et al. (2004) conclude that 'existing studies cannot provide a clear picture about the effect of environmental policy on the relocation of energy intensive industries; but they do indicate that - if a relation between environmental policy and relocation should exist - it is statistically weak.' (p. 165).

Kemfert (2002) considers the spillover and competitiveness effects of the Kyoto mechanisms used separately (Clean Development Mechanism (CDM), joint implementation (JI) and emission trading (ET)) using a general equilibrium model WIAGEM, on the assumption that Kyoto-style (with USA) action continues until 2050. The study shows the full welfare effect (percentage difference from business as usual) in 2050 divided into effects of domestic action, competitiveness and spillovers. Notable are the very small effects of the mechanisms on welfare: at most, as an outlier, there is an 0.7% increase for countries in transition for emissions trading and an 0.1% decrease for the EU15 for joint implementation. The CDM is seen mostly to improve welfare in developing countries. However the model does not include induced technological change or environmental co-benefits and it assumes full employment in all countries. If there were possibilities of the CDM leading to more technological development, more productive use of labour or an improvement in air or water quality, then the environmental and welfare effects in non-Annex I countries would be much larger than those reported.

Zhang and Baranzini (2004) have reviewed empirical studies of the effects of Annex I action on international competitiveness. The study by Baron and ECONEnergy (1997) for the Annex I expert group on the UNFCCC is typical of the studies reviewed. They report a static analysis of the cost increases from a tax of $100/tC on four energy-intensive sectors in nine OECD economies (iron & steel, other metals, paper & pulp and chemicals). Average cost increases are very low, less than about 3% for all country-sectors studied, with higher cost increases in Canada (all 4 sectors), Australia (both metals sectors) and Belgium (iron & steel). They conclude that 'empirical studies on existing carbon/energy taxes seem to indicate that competitive losses are not significant'. This supports the conclusions of the IPCC's *Third Assessment Report* (TAR), namely that 'reported effects on international competitiveness are very small and that at the firm and sector level, given well-designed policies, there will not be a significant loss of competitiveness from tax-based policies to achieve targets similar to those of the Kyoto Protocol.' (p. 589).

However, actions by Annex I governments (Denmark, Norway, Sweden, UK) have generally exempted or provided special treatment for energy-intensive industries, Babiker et al. (2003), suggest that this is a potentially expensive way of maintaining competitiveness, and recommend a tax and subsidy scheme instead. One reason for such exemptions being expensive is that for a given target, non-exempt sectors require a higher tax rate, with mitigation at higher cost.

2.3 Carbon Leakage

Carbon leakage is measured by taking the increase in CO_2 emissions outside the countries taking domestic mitigation action and then dividing by the reduction in the emissions of these countries. The IPCC's *Second Assessment Report* (1995) found a high range of variation in leakage rates from world models for OECD action from close-to-zero to 70%. The *Third Assessment Report* (TAR) (2001) found that the range had narrowed to 5% - 20% but noted that these estimates come from models with similar treatment and assumptions and that they do not necessarily reflect more widespread agreement. The TAR found that international permit trading substantially reduces leakage. The TAR also considered spillovers through the improvement in performance or reduction in cost of low-carbon technologies.

Over the last few years the literature has extended earlier analysis using equilibrium models to include effects of trade liberalisation and increasing returns in energy-intensive industries; and a new empirical literature has developed.

Equilibrium modelling of carbon leakage from the 1997 Kyoto proposal

Paltsev (2001) uses a static global equilibrium model GTAP-EG based on 1995 data to analyse the effects of the 1997 proposed Kyoto Protocol. He reports a leakage rate of 10.5%, within a sensitivity range of 5-15% covering different assumptions about aggregation, trade elasticities and capital mobility, but his main purpose is to trace back non-Annex B increases in CO2 to their sources in the regions and sectors of Annex B. The chemicals and iron & steel sectors contribute the most (20% and 16% respectively), with the EU being the largest regional source (41% of total leakage). The highest bilateral leakage is from the EU to China (over 10% of the total).

Kuik and Gerlagh (2003) using the similar GTAP-E model conclude that for Annex I Kyoto-style action "carbon leakage is modest, confirming an extensive set of earlier studies". They find that the major reason for the leakage is the reduction in world energy prices, rather than substitution within Annex I. They find that the central estimate of 11% leakage is sensitive to assumptions about trade-substitution elasticities and fossil-fuel supply elasticities and to lower import tariffs under the Uruguay Round. These sensitivities result in a range of 6% to 17% leakage.

In contrast to this consensus of global leakage for Kyoto-style action of about 10%, Babiker's (2005) paper presents findings that extend those reported in the SAR and the TAR. He extends a seven region, seven good and three industry global CGE model (similar to the other GTAP models except for the energy-intensive sector but with the earlier 1992 database). The distinctive extension is the inclusion of a treatment of increasing returns to scale and strategic behaviour in the energy-intensive industry. Assuming the adoption of the Kyoto Protocol by the OECD region, he presents four leakage rates, which depend on the assumptions adopted:

1. 20% for constant returns to scale and differentiated products (the Armington assumption)
2. 25% for increasing returns to scale (IRTS) and differentiated products
3. 60% for constant returns and homogeneous goods (HG)
4. 130% for the HG-IRTS combination

The main reason for the higher estimates is the inclusion of a treatment of increasing returns to scale and strategic behaviour in the energy-intensive industry. The 130% rate implies that OECD action leads to more global GHG emissions rather than less.

In assessing this high leakage finding it is important to understand the critical underlying assumptions.

1 The CGE model assumes a global social planner to maximise welfare, full information over space and time, perfect competition, and identical firms in each sector ('representative agents').

2 The composite energy-intensive good is treated as homogeneous. The high leakage rates come when the composite energy-intensive good has to pay carbon taxes or emission permit prices, and relocates abroad. The implicit assumptions of perfect substitution and no transport costs mean that production relocates without extra cost. However the composite good includes paper & pulp, chemicals and metals; so it is clearly very mixed in terms of technologies in supply and uses in demand. In fact, one country's production is not perfectly substitutable for that of another as assumed, since the mix will differ.

3 Increasing returns are included in only one sector. Adopting this assumption for the energy-intensive industry alone seems arbitrary since many other products are produced under increasing returns (electricity, machinery, vehicles, computers, software, and communications). Indeed the literature (eg McDonald and Schrattenholzer, 2001) does not emphasise the technologies used by energy-intensive industries. In consequence, given perfect substitution, all production is likely to relocate, depending on the assumed dynamics in the model, and with increasing returns, the production in the non-Kyoto countries will become more price competitive, hence the 130% leakage rates.

4 Adjustment to a new equilibrium is assumed to take place over many years (eg 18 years 1992 to 2010, when the calibrated base year is 1992 with a solution for Kyoto effects for 2010). In fact Kyoto action has largely taken place after ratification. For example, the EU emission trading scheme began in 2005. The result is a much shorter time for leakage than that assumed in the study. The structure of international trade has also changed substantially since the early 1990s, with developing countries, China in particular, becoming much more important in international trade.

The model shows that the energy-intensive industries will re-locate in response to the change in relative prices brought about by 28% carbon abatement below business as usual by 2010 (the paper does not state which policy is assumed). The result shows the potential for international trade to undermine unilateral environmental policies under special assumptions and conditions. In fact, mitigation action has tended to give preferential treatment to energy-intensive industries, and any trade quotas, eg steel quotas, will obstruct relocation.

The policy implications of such findings are that carbon leakage is potentially a serious threat to the effectiveness of mitigation policies. Special treatment of the energy-intensive sectors most affected reduces the threat, but also the overall benefits of the policies. The weakness of the equilibrium modelling is that it is based on one-year's data and assumptions such as global maximization of private consumption, homogeneous goods, constant returns to scale and perfect competition. The Babiker study shows that including increasing returns to scale in one sector in such models under an assumption of perfect substitution can lead to the wholesale transfer of that sector's output ie there are special conditions under which industries will re-locate.

However, such extreme results are not found in the empirical studies of carbon leakage as a general response to mitigation under the Kyoto Protocol.

Sijm *et al.*, (2004) summarise these modelling results. 'Models provide a useful, but abstract tool for climate policy analysis; they are faced by several problems and limitations with regard to practical policy decision- making, including problems such as model pre-selection, parameter specification, statistical testing or empirical validation.' (p. 14).

Empirical analysis of carbon leakage

Sijm *et al.*, (2004) also provide an empirical analysis of carbon leakage from energy-intensive industries. The authors argue that the simple indicator of carbon leakage is insufficient for policy making. The potential beneficial effect of technology transfer to developing countries arising from technological development brought about by Annex I action is substantial for energy-intensive industries, but has so far not been quantified in a reliable manner. 'Even in a world of pricing CO_2 emissions, there is a good chance that net spillover effects are positive given the unexploited no-regret potentials and the technology and know-how transfer by foreign trade and educational impulses from Annex I countries to Non-Annex I countries.' (p. 179).

In the empirical analysis of effects in energy-intensive industries there are many other factors besides the price competitiveness considered in the modelling studies reporting high leakage rates. They conclude that, in practice, carbon leakage is unlikely to be substantial because transport costs, local market conditions, product variety and incomplete information all favour local production. They argue that the simple indicator of carbon leakage is insufficient for policy making.

Using a detailed model of the world industry, Szabo et al. (2006) report production leakage estimates of 29% for cement with an EU ETS allowance price of €40/tCO_2. Leakage rates rise the higher the allowance price. More generally, Reinaud (2005) surveys estimates of leakage for energy-intensive industries (steel, cement, newsprint and aluminium) with the EU ETS. She comes to a similar conclusion and finds that with the free allocation of CO_2 allowances 'any leakage would be considerably lower than previously projected, at least in the near term.' (p. 10). However, 'the ambiguous results of the empirical studies in both positive and negative spillovers ... warrant further research in this field' (p. 179).

Analytical studies of climate policy models that focus on the steel industry found that the stricter the climate policy, the higher the rate of carbon leakage. With carbon prices of around €10/t CO_2, rates of around 25-40% of carbon leakage from Annex I to non-Annex I countries were found due to the relocation of production. Two of the models also found that leakage was greater with increases in tax rates at low carbon prices compared with high prices. However, there are uncertainties surrounding these models as they are not specified to consider whether elasticity of demand for products determines the location of production across countries. The models also try to estimate the impact of future climate change policies on the incidence of carbon leakage, rather than those in the past. Technological spillovers are also not represented from industrialised to developing countries, which are considered the most important market for technology implementation. These technologies reduce the demand for fuel use and therefore the level of CO_2 emissions. Thus, these models have not provided significant evidence that environmental regulation promote the relocation of high-polluting industries.

Sijm *et al.* (2004) also argued from their empirical analysis that environmental policy has not been a significant decision criterion for the location of investment and is not a key explanatory factor for investing in energy-intensive processes in developing countries, as the cost effects of environmental regulation are found to be small.

Past experience also suggests that shifts in production shares in the global market have not clearly been due to past environmental policy changes. This production shift has been driven by market size, growth in regional demand (due to developments in new markets and increasing demand in developing countries) and wage levels rather than by a decrease in competitiveness of industrialised countries compared with developing countries. This has been observed for the steel industry where strong demand for these products has seen a shift in production to the developing countries such as China. Even if relocation in production to developing countries occurs, industries, such as iron & steel, tend to use the most recent technology as this minimises planning costs and maintenance costs. Therefore it is not obvious that cost effects of environment policy are influential motives for relocation.

For the purpose of investigating carbon leakage within the EU, there is not enough literature on carbon leakage to warrant conclusions about the effects of climate change policies of one Member State on emissions elsewhere in the EU. The same arguments apply as to those between Annex I and non-Annex I countries in a global context, but technological transfer within the EU is likely to be easier, and the cross-border activities of multinationals are more extensive. Barker (1998) provides estimates of leakage from unilateral policy action by EU Member States for a 10% reduction in GHGs by 2010. These can be found in Table 2.1.

The results show that leakage can raise or lower emissions, but the estimates of leakage are very small in relation to the effects in the countries taking action.

TABLE 2.1: PROJECTIONS OF CO2 REDUCTIONS IN MEMBER STATES, 2010

	Difference from Baseline case in mtC	
	Effects of unilateral action internal to the Member State	Effects of unilateral action in the rest of the EU
Belgium	-5.8	0.1
Denmark	-0.9	0.0
West Germany	-16.9	0.1
Spain	-8.0	-0.6
France	-14.7	-0.6
Ireland	-1.3	0.0
Italy	-13.1	-0.1
Luxembourg	-0.2	0.0
Netherlands	-2.5	0.1
Portugal	-1.0	0.0
United Kingdom	-14.9	0.3

Source(s) : Barker, T. (1998) p.1094.

2.4 Technological Spillovers

Mitigation action may lead to more advances in mitigation technologies. Transfer of these technologies, typically from industrialized nations to developing countries, but in Europe from the old to the new Member States, is another avenue for spillover effects. Effective transfer implies that the states receiving the new technologies have an active role in both the development and the adaptation of the technologies. The transfer also implies changed flows of capital, production and trade between regions.

The existence of spillover effects also changes the theoretical conclusions in the economics literature. In the pure competition equilibrium model, the most efficient policy is an equal rate of carbon tax for every sector and region. Rosendahl (2004) shows that for maximum efficiency with spillovers and learning-by-doing, the carbon tax should be higher in those sectors and regions with the highest potential for technological progress. This is a general argument for stronger mitigation in those sectors and countries where technological progress is most likely to be accelerated by higher taxes on carbon use. He concludes by qualifying this finding, noting the possible effects of a lock-in to a low-carbon technology, such as nuclear or wind power.

> ‘One important policy question is then whether subsidising an existing technology may hamper the introduction of new technologies with larger potential, thereby resulting in lock-in of inferior technologies. Furthermore, to what extent do the relative merits of taxes versus subsidies depend on the characteristics of a new technology? Will the optimal subsidy of an existing alternative energy source change if there are possibilities of new technologies coming into force, and how is this dependent on spillovers from the new technology?’

Sijm et al. (2004) provide an assessment of spillover effects of technological change. They divide the literature into two groups, depending on their ‘top-down’ or ‘bottom-up’ approach to modelling. They review the treatment of spillovers in the top-down modeling studies and find that most of them omit the effect or have it playing a minor role. However the literature is developing rapidly in this area. They find that the bottom-up modelling studies are more consistent in their treatment and come to closer agreement in their results. The effects of spillovers combined with learning-by-doing is explored specifically by Barreto and Kypreos (2004), using MARKAL, and Barreto and Klaassen (2004), using ERIS. They find that owing to the presence of spillovers, the imposition of emission constraints in the Annex I region may induce technological change and, hence, emission reductions in the non-Annex I region even when the latter region does not face emission constraints itself (Sijm, 2004 p. 68).

3 Modelling the EU Energy-Environment-Economy System with E3ME41

3.1 Introduction to E3ME

Background E3ME (Energy-Environment-Economy Model for Europe) is a general model for Europe designed to address issues that link developments and policies in the areas of energy, the environment and the economy (see Barker, Gardiner and de Ramon (2002)). The European economy is becoming more and more integrated; at the same time, the relationship between economic activity, energy use and the environment is of pressing concern for European policy and political debate.

The guiding principles of the model are such that it is:

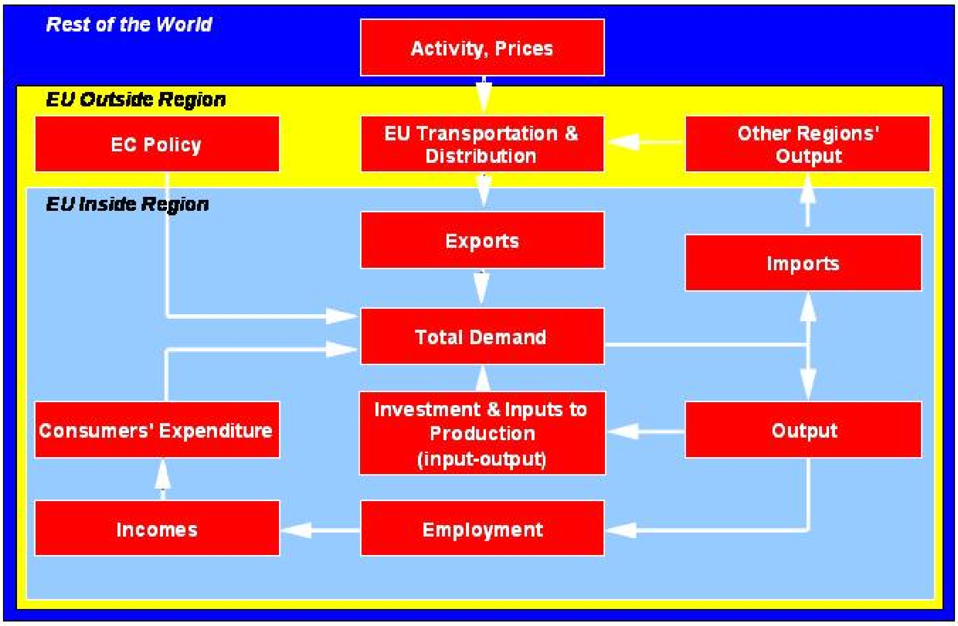
- elaborated at a European rather than at a national level, with the national economies being treated as regions of Europe
- dealing with energy, the environment, population and the economy in one modelling framework and allowing short-term deviations to occur while convergence to a long-run outcome takes place
- designed from the outset to address issues of central importance for economic, energy and environmental policy at the European level
- capable of providing highly disaggregated short- and long-term economic and industrial forecasts for business and government
- capable of analysing long-term structural change in energy demand and supply and in the economy
- focused on the contribution of research and development, and associated technological innovation, on the dynamics of growth and change

Antecedents E3ME is a multisectoral dynamic regional econometric model capable of providing a long-term equilibrium solution. The model uses input-output tables, but combines them with the time-series analysis used in macroeconometric models. It has been developed following the structure of a regionalised E3 model of the UK economy (Barker and Peterson, 1987) which has been used to analyse in detail the effect of the EC carbon/energy tax on the UK economy. Models in the same tradition for national economies have been developed by the INFORUM group of modellers (see Almon, 1991).

The E3ME model E3ME version 4.1 is comprehensively described in the model manual (http://www.camecon-e3memanual.com/), which includes a full set of results from the estimated equations.

Figure 3.1 shows how E3ME can be represented as a regional, econometric input-output model. Most of the economic variables shown are at a 42 industry level (NACE-CLIO 25 with expanded fuel and power sectors, including 16 services sectors) and cover the time period 1970-2002. The whole system is solved simultaneously across all the industries and regions (the EU25 plus Norway and Switzerland). More information on the E3ME model can be found at the main model website, http://www.e3me.com/.

FIGURE 3.1: E3ME41 AS A REGIONAL ECONOMETRIC INPUT-OUTPUT MODEL

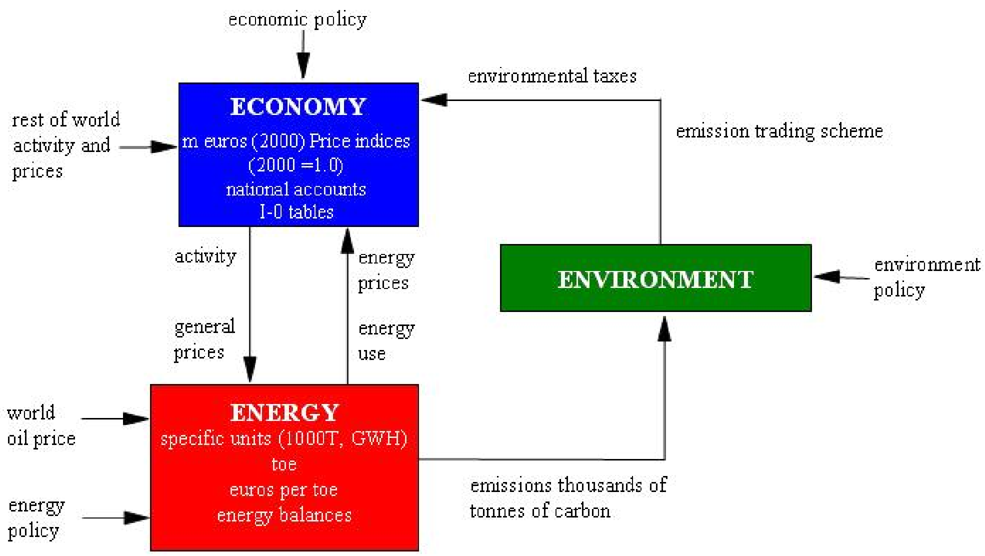


E3 modelling in E3ME

Figure 3.2 shows how the three components of the model - energy, environment and economy - fit together. Each component is shown in its own box and utilises its own units of account and sources of data. Each data set has been constructed by statistical offices to conform with accounting conventions. Exogenous factors coming from outside the modelling framework are shown as inputs into each component on the outside edge of the chart. For the EU economy, these factors are economic activity and prices in non-EU world areas and economic policy (including tax rates, growth in government expenditures, interest rates and exchange rates). For the energy system, the outside factors are the world oil prices and energy policy (including regulation of energy industries). For the environment component, exogenous factors include policies such as reduction in SO2 emissions from large combustion plants. The linkages between the components of the model are shown explicitly with arrows showing which values are transmitted between components.

The energy price data in E3ME comes from the IEA and does not include sector-specific pricing (ie all industry groups are assumed to pay the same price for their various fuel inputs). Although sector-specific prices are available for some regions, this is not available on a consistent basis across Europe. However, this is a key assumption because the expected sectoral effects of ETR will be directly related to the fuel prices paid by that sector – for example a tax of 10€/toe will have a much larger relative effect when the fuel price excluding taxes is 50€/toe than when the fuel price is 100€/toe. This assumption means that results sectors made up of large firms that can purchase fuels at lower prices (such as paper and pulp) are probably being understated, and those with many small firms may be being overstated.

FIGURE 3.2: E3ME AS AN E3 MODEL



The data E3ME's historical database is constructed from data from Eurostat, DG ECFIN (AMECO) and the OECD secretariat's STAN database. These sources have the advantage of covering the whole EU on a consistent basis (as far as possible), but the data are usually published later than the corresponding data from national sources. These data have been supplemented by standardised data from other sources when required, to form completed time series. For more information about the coverage of the data, the reader should refer to the model manual.

3.2 Modelling Foreign Trade in E3ME41

Introduction The role of trade is central to analysing to the analysis of competitiveness of an individual region or industry. Trade is an important feature in a regional model such as E3ME for two main reasons. First, European integration has led to a rise of degree of openness in many EU markets, with an associated rise in the ratio of exports to total final demand. Second, exports and imports represent the linkage between the regions in E3ME, so any effects moving from one region to another are transmitted through this area of the model. The modelling of exports and imports is similar in structure, in terms of income and price effects and also because they use similarly constructed variables.

All trade is treated as if it takes place through a European pool. The export and import volume equations represent each region's exports into this pool and imports from it. Total exports and imports have been separated into two sub-components, one for intra-EU trade and one for extra-EU trade. However, it is not possible to identify separate trade prices for intra- and extra- EU trade, and therefore the export and import price specifications are for all exports and imports, regardless of destination or source.

The determinants of export volumes in the model can be separated into two groups of effects, those associated with income and those with prices. A proxy for technical progress (accumulated gross fixed investment plus R&D expenditure) is also included in the equations (see below). The basic model of trade prices used in E3ME assumes that the EU regions operate in oligopolistic markets and are each small economies in relation to the total market. This assumption about market structure implies that, apart from a few commodities (eg crude oil) whose price is set exogenously, prices are typically set by producers as mark-ups on costs, ie unit costs of production.

Export and import volumes

Both export and import volumes are split into intra- and extra- EU trade for each region and sector, and a separate equation is estimated in each case.

The export volume equation can be separated into three effects, income, prices and technical progress. The income effect is captured in the form of two variables, the first dealing with economic activity in the rest of the EU, the other concerning activity in the rest of the world. Price effects are split into three forces: the price of exports, the price of exports in other EU countries, and a 'rest of the world' price variable. All prices are converted to euros. Homogeneity is imposed between the price effects, such that the combined value of the external price coefficients (other EU and rest of world) are set equal to the overall export price. This is another way of combining the price terms in a relative, rather than absolute, form. The technical progress indicators (see below) are also included to help capture the role of innovations in trade performance. This variable could be measured relative to that of competitors, but since this would imply no effect on trade if competitors undertook equal proportions of investment/R&D this did not seem to be a worthwhile exercise.

In the equation describing intra-EU and extra-EU import volume, activity is modelled by sales to the domestic market, while the three price effects are import price, price of sales to the domestic market and the relative price of the currency, ie the euro exchange rate. Aside from the restrictions on sign and significance, price homogeneity is imposed between the price of imports and price of sales to the domestic market. As with the export equation, this has the effect of making the price relative, removing the long-term effect of the exchange rate variable. The technical progress measure is again included to allow for the effects of innovation on trade performance.

An additional variable, SVIM, has been added to both the export and import equations to take account of the Internal Market programme. SVIM is a synthetic variable that has a value of zero until 1985, and then gradually increases (following an exponential pattern) to a value of unity in 1992 and increases further with the introduction of the euro. SVIM is set to zero in the extra-EU trade equations.

Export and import prices

The equations for export and import prices play a large role in the response to exchange rate movements, acting as an important transmission mechanism for effects such as devaluation, eg the exit of sterling and the lira from the ERM in September 1992. The effects can be dissipated in a number of ways, for example creating inflationary pressures or leading to movements in the balance of payments. The basic model of trade prices used in E3ME assumes that the EU regions operate in oligopolistic markets and are each small economies in relation to the total market.

Certain commodities (eg crude mineral oil) have prices treated exogenously, but the majority are treated in the following manner. Following from the assumption on market structure, prices are set by producers as mark-ups on costs, ie unit costs of production. Aside from this, the same variables are used for both import and export prices, within a general log-log functional form.

Alongside the unit cost variable, there are four price terms included in each regression to deal with developments outside the region in question. They are an 'other EU' price (created in the same manner as described in the trade volume equations), a 'rest of world' (ie outside EU) price, a world commodity price variable and the euro exchange rate itself.

The measures of technical progress (described in detail below) are also included to cope with the quality effect on prices caused by increased levels of investment and R&D. Restrictions are imposed to force price homogeneity and exchange rate symmetry on the long-term equations, again in much the same manner for the trade volume equations.

Due to the complexities and non-economic factors involved exchange rates are treated as exogenous in E3ME. Thus a large shift in trade balances will not automatically affect the competitiveness of domestic industry. This is worth bearing in mind when considering the impact of ETR on trade prices; and gains or losses could easily be exceeded by a relatively small exchange rate movement.

3.3 Non-price Competitiveness in E3ME41

The role of R&D expenditure and investment

The technical progress indicators are used as a measure of innovation and product quality and estimate the non-price competitiveness of an industry. Ideally, E3ME could incorporate measures of innovatory activity in each EU Member State, relative to the same activity in its main competitors, at a detailed industrially disaggregated level on an annual basis, covering the period 1970-2002, but limited data restrict the choice of inputs. The decision as to which data to use as a representation for innovation comes down to a choice between two alternatives: patents; and research and development activity. In each case the available information has to be mapped into the industrial classifications used in the E3ME model. This requires a very detailed examination and comparison of the systems of classification used in each case, sometimes involving comparisons across countries.

Data on patents

Patenting activity represents one measure of innovatory activity. It is well established that different industries have different propensities to patent. A potentially valuable data set exists in the form of the series collected in the United States by the Department of Commerce, Office of Technology Assessment and Forecasts (OTAF). These data indicate the level of patenting activity by industry conducted by most major states within the US. Given the latter's key role in innovation and the world economy generally, these data provide a potentially very useful measure of relative innovatory activity in different countries. However, the data suffer from a number of limitations as far as the present exercise is concerned: the time series only cover the period from 1968; the industrial classification used is a US one; and finally, by their nature, patents tend to focus attention on manufacturing industries rather than the service sectors. It should be noted that there is ongoing work at the OECD to compile an industry database of patents, which may be a valuable input to E3ME in the future.

R&D expenditures

An alternative measure of innovation is Research and Development Expenditure (and related employment). In contrast to the patents indicator this is a measure of input rather than output from innovatory activity. The OECD publishes a series of data on R&D activity by industries for major economies, known officially as the ANBERD database. These, in principle, enable relative measures of Member States' performance to be constructed. In practice, the OECD data are based on irregular surveys conducted within each individual country. There are therefore large numbers of missing observations. A considerable amount of interpolation and adjustment is therefore necessary to convert these data into a usable form for time series analysis. They also suffer from similar problems of matching industrial classifications and time scale coverage as the other series already discussed. These data have been extended to 2003 and are the basic measure of innovatory activity used in the estimation of the equations of E3ME.

The ANBERD database covers only business enterprises, ie not the public sector, which means that extra work was required before public sector R&D, including defence spending, could be identified. For this type of disaggregation, which was also required in E3ME30, a separate OECD survey based on the Frascati Manual was used which distinguishes military R&D expenditure for each Member State. In addition, the International Energy Agency (IEA) has published annually for the last few years a detailed analysis of OECD states' spending on energy-related R&D, including energy-conservation R&D. This provides detail of large-scale R&D programmes in EU member States funded by national governments.

Unfortunately the data on privately-funded energy-saving R&D are partial and incomplete, so it is not possible to present data or results for total energy-saving R&D.

Gross investment in Fixed Assets

Detailed data for investment demand (Gross Domestic Capital Formation) in European countries, in both a constant and current price base, are published by Eurostat and are available as part of the OECD's STAN database. E3ME disaggregates investment into the 42 industry sectors used throughout the model, and gaps in the published data were filled using the previous version of the E3ME database (version 3.0). The units are standardised to euros (current prices) and 2000-valued euros (constant prices) for all the E3ME regions.

Method

Expenditure on investment and innovation mainly enter E3ME's equations indirectly, by their use in formulating a measure of technical progress. The approach to constructing the measure of technological progress in E3ME is adapted from that of Lee et al (1990). It adopts a direct measure of technological progress (T_t) by using cumulative gross investment, but this is altered by using data on R&D expenditure, thus forming a quality-adjusted measure of investment. The equation for T_t is written as

$T_t = c + a d_t(\tau_1)$ (3.1)

where dt(τ1) satisfies the following recursive formula

$d_t(\tau_1) = \tau_1 d_{t-1} - \tau_1 + (1 - \tau_1)\log(GI_t + \tau_2 RD_t)$ (3.2)

where

GI_t = the level of gross investment

RD_t = constant price research and development expenditure

τ_1 = a measure of the impact of past quality adjusted investment on the current state of technical advance, while

τ_2 = a measure of the weight attached to the level of R&D expenditure.

To initialise the recursive process for d_t, the assumption is made that in the pre-data period the process generating $\log(GI_t)$ is characterised by a random walk. Under this assumption the first value of d_t can be written as

$d_0 = \log(\mathrm{GI})$ (3.3)

where the right hand side represents the average of gross investment over the first five year sample period. The values of τ_1 and τ_2 were set at 0.3 and 1.0 respectively, while noting that more sophisticated procedures could have been adopted, ie a grid search method based on log-likelihood values. The series $d_t(\tau_1)$ is then calculated by working the recursive procedure forward given the initial value, d_0.

In E3ME41 there are two technical progress indicators, one which measures technical progress related to ICT investment in the new economy, and one which is related to all other investment. The construction of the two indicators is similar, with investment split up into ICT and non-ICT related investment, and τ_2 set to 0 in the non-ICT investment measure (ie All R&D expenditure influences the ICT measure).

The two technical progress indicators appear together in the equations outlined below, and separate long- and short-term parameters are estimated for each one. Due to a lack of data, a single indicator is maintained for the EU's new member states.

Use of the TPI measures

The variables used to represent technological progress enter a variety of equations in E3ME version 4.1, including:

- employment

The technological progress variables are included as part of the implicit production function that lies behind the factor demand equations in E3ME. The effect on employment demand is deemed ambiguous, as this greatly depends on whether the type of technical progress is labour-saving or labour-augmenting. The extra activity of R&D itself, however, is likely to be more labour-intensive than average production in most industries.

- hours-worked

The presence of technical progress in determining average hours-worked originates in the determination of the optimal number of hours worked as part of the representative firm's cost minimisation process. A negative sign is imposed on the coefficients for technological progress, based on the assumption that an increase in investment R&D will improve the efficiency of the capital stock, thus requiring less average hours-worked for a given number of employees.

- industrial prices

A positive effect was imposed on the technological progress variable to cope with the quality effect that increased investment/R&D is expected to have, ie the role of product innovation. The effect of process innovation (which would be expected to lower prices) is taken account of by a measure of unit costs, which is a separate variable in the equation.

- export and import volumes

The technical progress indicators are included to help capture the role of innovations in trade performance. This variable could be measured relative to that of competitors, but this has not been implemented in E3ME4.1. (However, if it was only relative technical progress that improved performance and if all countries experienced such progress simultaneously, then there would be no effect on economic growth; this does not appear to be very plausible as a characterisation of modern industrial and service economies). The anticipated effects are a positive elasticity for export volumes and a negative elasticity for import volumes.

- export and import prices

The measures of technical progress are included to cope with the quality effect on prices caused by increased levels of investment and R&D, and progress is assumed a priori to have a positive effect on export prices and a negative effect for import prices.

- energy demand

The energy demand equations include both gross investment and R&D spending directly as explanatory variables. These terms are intended to capture the effects of new ways of decreasing energy demand (energy-saving technical progress) and the elimination of older inefficient technologies. This will also take into account the introduction of new energy-saving techniques and methods of energy conservation, and hence is expected to be negative. In particular, technical progress in the industries producing machinery, electronics and electrical equipment is expected to reduce aggregate energy demand and technical progress in the motor vehicles industry is expected to reduce the demand for oil, as transport equipment becomes more efficient and alternative energy sources are adopted.

3.4 The Effects of GHG and Energy Taxation

Introduction and assumptions

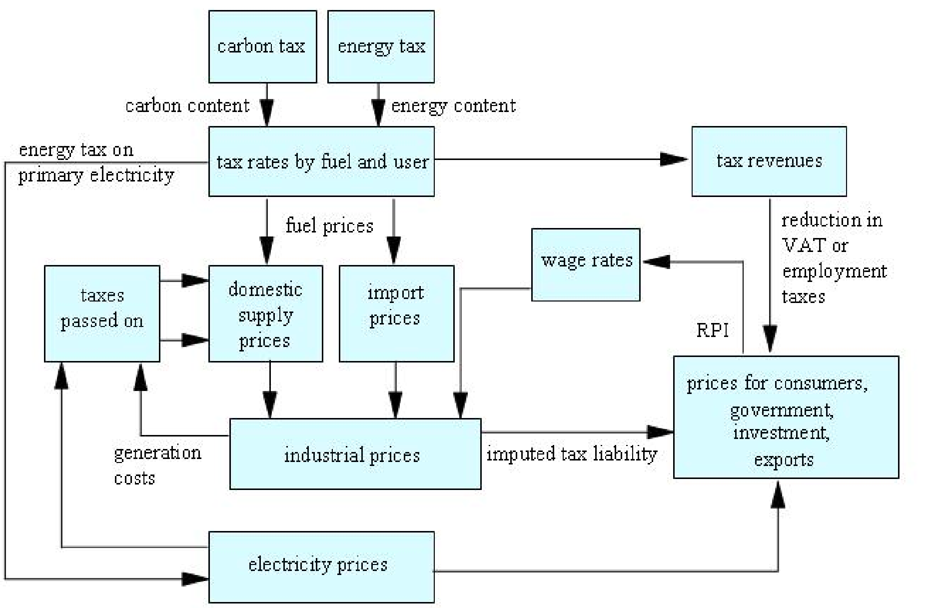
One of the purposes of E3ME is to provide a consistent and coherent treatment of fiscal policy in relation to greenhouse gas emissions. Figure 3.3 shows how tax rates affect prices and wage rates in the model; the mechanism is the same for taxes on other emissions and energy.

There are inevitably certain simplifying assumptions required in this kind of modelling.

First assumption

The first assumption is that the effects of the tax in the model are derived entirely through the impact of the tax on fuel prices, and through any use of the subsequent

FIGURE 3.3: THE IMPACT OF THE CARBON/ENERGY TAX ON PRICES AND WAGE RATES



revenues from the tax in reducing other taxes. Other effects are not modelled. For example, if the introduction of such a tax caused the electricity industry to scrap coal-burning plant in advance of what might be expected from the relative price change induced by the tax, this effect would have to be imposed on the model results. The one exception to this rule is the announcement effect of the UK CCL (see chapter 7).

All the energy and emission taxes are converted into a consistent set of units (€/toe). These taxes are then added to the costs of the fuels. Tax revenues can be calculated from fuel use; the revenues will be reduced according to the fall in use, but will rise according to price inflation and any escalator in the tax rates. In the Baseline case, effective tax rates are calculated by dividing fuel use by raised revenues, this includes any exemptions and non-payments, which the raw data for tax rates on its own does not.

Second assumption

The second assumption is that imports and domestic production of fuels will be taxed according to the energy content of the fuels, but that exports are exempt from the tax coverage. The treatment is assumed to correspond to that presently adopted by the authorities for excise duties imposed on hydrocarbon oils. It is assumed that industries and importers pay the tax, and that it is then passed on in the form of higher fuel prices paid by the fuel users. A further assumption is that industrial fuel users pass on all the extra costs implied by the tax in the form of higher prices for goods and services. The increase in final price will be a result of the direct and indirect energy content of each commodity distinguished in the model. If the revenues are used to reduce employer tax rates, then industrial employment costs will fall and these reductions in costs are also assumed to be passed on through the industrial system.

ETR effects on the E3 system

In considering the competitive response of different sectors and companies, there are two important questions to be answered:

- are the prices of the product set in the world markets or by the producer or in the local markets?
- how flexible is the process of production in responding to an increase in costs?

If the price is fixed in the world market, then no increase in costs arising from an increase in energy taxes can be passed on to prices. If the process of production is also fixed (eg because the product requires long-lived capital stock), then it might be very expensive to change the technology or move the plant; so all extra costs must be paid out of profits. If the industry or the company is not profitable, then the extra costs could lead to plant closing. However, this is an extreme outcome and most industries and companies have the ability to pass extra costs on to their customers and to change their production process to reduce emissions and avoid some of the increase in taxes.

For these reasons, changes in manufacturing export and import volumes do not give enough information about the effects on competitiveness. The effects on unit costs can be compared to those on export prices to see which sectors have their profit margins squeezed by being forced to accept world prices for their products, while at the same time being unable to avoid increases in their unit costs (see Barker 1998).

The net effect on industrial and import prices will eventually feed through to consumer prices and will affect relative consumption of goods and services depending on the carbon/energy content and on their price elasticities. The higher consumer prices will then lead to higher wage claims. The econometric evidence supports the theoretical presumption that all the tax is eventually paid by the final consumer; and this condition is imposed in the long-term solution of the model.

Figure 3.4 shows the effects of these price and wage rate changes on fuel use, CO2 emissions and industrial employment. The changes in relative fuel prices as a result of the tax will change fuel use, depending on substitution elasticities. The fuel price increases will be passed on to more general increases in prices, which will cause substitution in consumers' expenditure, in exports and between imports and domestic production. These changes will feed back to fuel use. CO2 emissions are derived directly from the use of different fuels. If employment costs are reduced when tax revenues are recycled, then industrial employment will be stimulated directly, with a further indirect effect as labour-intensive goods and services gain in relative price competitiveness.

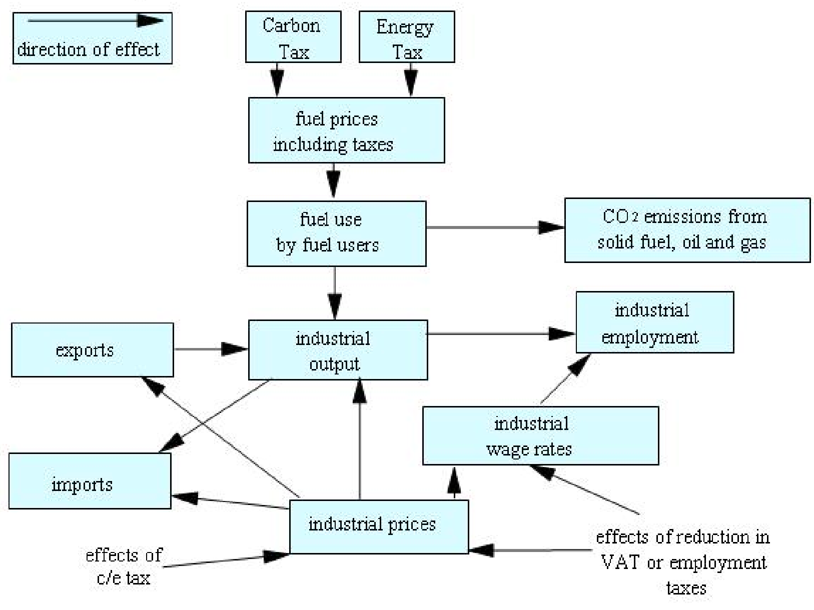
3.5 The Effects of the Various Revenue Recycling Mechanisms

The COMETR scenarios assume that the ETRs in each country are revenue neutral in each year; in this way the results presented in Chapter 7 describe a shift in the tax burden to energy use from the more general economy, rather than an increase in the overall tax burden. Of the six countries examined, a variety of methods were used to recycle the tax revenues and in some cases a combination of methods were used. These are outlined in the list below. For several countries no explicit revenue recycling mechanisms were put in place, either because the tax reforms were part of such a wide package that it was impossible to determine what the alternative tax arrangements would be, or simply because no provisions were put in place at the time. In these countries it is assumed that revenue neutrality is achieved through a shift in income taxes. This was judged to be the most non-controversial way of maintaining revenue neutrality, as the ETR revenues are very small when compared to the overall level of income tax revenues.

The revenue recycling methods considered in E3ME are changes in:

- Income Tax

FIGURE 3.4: THE IMPACT OF THE CARBON/ENERGY TAX ON FUEL USE, CO_2 EMISSIONS AND INDUSTRIAL EMPLOYMENT



- Employers' social security contributions
- Employees' social security contributions
- Benefit rates
- Investment in energy-saving technology

The first four methods of revenue recycling relate to the labour market. By changing income tax, the government is directly affecting (nominal) disposable incomes. For example a reduction in income tax will increase disposable income, all other things being equal. The immediate effects are likely to be a boost to household spending, particularly on luxury goods. We would also expect to see an increase in investment in dwellings. Through multiplier effects there will be further increases in average incomes, as domestic firms require more inputs to meet the extra demand, including labour.

In the longer term, a 1% increase in household income will lead to an equivalent 1% increase in overall consumer spending, in line with conventional economic theory. Higher employment and lower unemployment may cause some increase in wages.

The case of social security payments is interesting. The effects of changing employees' contributions are almost identical to the effects of changing income tax rates. This makes intuitive sense as the payments by employees are the same, even if the treatment of the tax by government is different (the government sector is largely exogenous in E3ME). The main reason for including this separately to income tax is to simplify the processing in Germany, where there were equal reductions in employers' and employees' contributions.

The initial effect of reducing employers' social security contributions is to lower the cost of labour to firms, and hence should lead to a direct increase in employment. The effects of this will be two-fold: first, there will be an increase in average household incomes from higher employment rates; there could also be a slight increase in average wages if unemployment falls. Both effects would lead to an increase in average household incomes and, possibly, a short-term increase in household consumption. The overall inflationary impact will be dependent on the relative strengths of these two effects (eg labour-intensive firms will have the largest initial fall in costs and wages will increase faster if the economy is close to full employment), but overall the effects are similar, an increase in average household incomes driving forward consumer spending.

The effects of changing benefit rates are slightly different. If the government increases benefit rates, this increases the disincentive to work. The magnitude of this effect varies across the regions of Europe but, overall, we would expect to see a decrease in employment and labour market participation. In pure economic terms, increasing distortions in the labour market is not seen as a way of increasing productivity and economic output.

By increasing investment in energy-saving products, a government is hoping to achieve a decrease in energy consumption over and above the reduction due to the price effect of higher taxes alone. There will be some other positive effects; however, as investment tends to improve the overall quality and desirability of an industry's output (ie increased non-price competitiveness). Previous research has found these effects to be particularly strong in international trade in the long term. More immediately, there will be a boost to industries producing capital goods, such as construction and motor vehicles.

3.6 A Brief Description of E3ME's Labour Market

E3ME includes a detailed treatment of the labour market with stochastic equations for employment (as a head count), average wages, hours worked and labour market participation. This plays an important role in the scenarios, particularly in cases where tax revenues are recycled through the labour market. Unemployment is calculated as the difference between employment and the active labour force and is a key explanatory variable in the equations for wages and household consumption. Unlike many CGE models, E3ME does not assume full employment, even in the long run.

For more details about the exact specifications of E3ME's equations see chapter 8 of the model manual, available online at http://www.camecon-e3memanual.com/cgi-bin/EPW_CGI.

The employment equations

Employment is modelled as a total headcount number for each industry and region as a function of industry output, wages, hours worked, technological progress, and energy prices. Industry output is assumed to have a positive effect on employment, while the effect of higher wages and longer working hours is assumed to be negative. The effects of technical progress are ambiguous, as investment may create or replace labour; this will vary between sectors.

Depending on available data, it may be possible to estimate different equations for male and female employment; however it is unlikely that employment in different age groups could be estimated.

The hours worked equations

Hours worked is a simple equation, where average hours worked by industry and region is a function of "normal hours-worked" (hours worked in other industries and regions) and technological progress. It is assumed the effects of technical progress gradually reduce average hours worked over time as processes become more efficient. The resulting estimate of hours worked is an explanatory variable in the employment equation (see above).

Hours worked is defined as an average across all workers in an industry, so incorporates the effects of higher levels of part-time employment in certain regions and industries.

The wage equations

In E3ME wages are determined by a complex union bargaining system that includes both worker productivity effects and prices and wage rates in the wider economy. Other important factors include unemployment, tax rates and cyclical effects. Generally it is assumed that higher prices and productivity will push up wage rates, but rising unemployment will reduce wages. A single average wage is estimated for each region and sector.

The estimates of average wages are a key input to both the employment equations and the price equations in E3ME. In the absence of growing output, rising wages will increase overall unit costs and industry prices. These prices may get passed on to other industries (through the input-output relationships), building up inflationary pressure.

The labour market participation equations

Labour market participation is estimated as a rate between 0 and 1 for male, female and total working-age population. At present there is no disaggregation by age groups. Labour market participation is a function of output, wages, unemployment and benefit rates. Participation is assumed to be higher when output and wages are growing, but falls when unemployment is high, or benefits create a disincentive to work. In addition, there is a measure of economic structure and the relative size of the service sector of the economy; this has been found to be important in determining female participation rates.

The participation rates determine the stock of employment available (by multiplying by working-age population, which is exogenous). This is an important factor in determining unemployment, which in turn feeds into wages and back to labour market participation.

4 Processing the COMETR tax data

This chapter outlines the main stages of processing the tax data set after it was received by Cambridge Econometrics from NERI (except for the UK data set which was obtained from ONS). The aim of this work was to obtain a set of data that could be stored on the E3ME databanks and used in the analysis in the COMETR scenarios.

4.1 Model Classifications

The E3ME model was extended to include two new classifications

Two new classifications were added to the E3ME model so that it could cope with the new tax data. These were the CT (COMETR Tax) classification, and the CR (COMETR Revenue-Recycling) classification.

The CT classification (see Table 4.1) lists all the taxes that are used in the COMETR scenarios. This is not to say that other taxes were ignored, nor that further detail was not used, but it was possible to express all the taxes as an element in this classification. In addition, specific industry information was added at a later stage where it was available.

It should be noted that initially there were 26 elements in the CT classification as energy, CO2 and other emission taxes were separated, but as these taxes are both in terms of euros / toe energy use (or equivalent measure) they could be simply added together and there was no information gained from keeping them separate. In addition, much of the tax revenue data combined energy, CO2 and other emission tax receipts so this proved to be a more efficient use of data. On advice from NERI, the original classification was expanded to include petrol and diesel separately rather than a single motor spirit entry.

TABLE 4.1: THE CT CLASSIFICATION

1. Industry energy and CO2 tax: Coal
2. Industry energy and CO2 tax: Oil (heating)
3. Industry energy and CO2 tax: Gas
4. Industry energy and CO2 tax: Electricity
5. Industry energy and CO2 tax: Petrol
6. Industry energy and CO2 tax: Diesel
7. Household energy and CO2 tax: Coal
8. Household energy and CO2 tax: Oil (heating)
9. Household energy and CO2 tax: Gas
10. Household energy and CO2 tax: Electricity
11. Household energy and CO2 tax: Petrol
12. Household energy and CO2 tax: Diesel

TABLE 4.2: THE CR CLASSIFICATION
1. Reduction in income taxes
2. Reduction in employers' social security contributions
3. Reduction in employees' social security contributions
4. Increase in state benefits (inc pensions)
5. Additional government investment (2000 prices)

The CR classification (see Table 4.2) handles the various revenue recycling mechanisms employed in the ETRs considered in COMETR.

4.2 Rates, Revenues and Revenue Recycling

Three main types of input data were required

E3ME's energy and environment databanks already contain detailed data on fuel demand, by 19 fuel users and 12 fuels (source: IEA). This forms the base for the tax. The tax rates were received from NERI using a spreadsheet template provided by Cambridge Econometrics that was based around the classifications outlined above.

Tax rates are required by E3ME to estimate the increase in the cost of fuels as a result of the ETR. This then feeds into the energy submodel, the fuel demand equations and then into the rest of the model.

Tax revenues are also required. It would be intuitive to say that tax revenues should be equal to tax rates * fuel use but this misses out an important part of the modelling (and indeed the focus of one scenario) in that the full tax rates are rarely paid at a macro level. This may be due to special exemptions to specific industries or households, or the failure of central governments to collect tax. In the COMETR Reference case, the effective tax rates are determined by the tax revenues divided by fuel use. While this makes some attempt to take into account exemptions and non-payments it turned out that the data for tax revenues were generally much harder to obtain and are published at a more aggregated level, so assumptions had to be made on a case-by-case basis. See the following sections for more details.

The revenue recycling is an important part of the modelling in E3ME, and in some cases may have a larger impact than the energy taxes. Therefore it is important that the scenario results demonstrate the most accurate profile of revenue recycling possible, and are not biased by any changes in the overall level of taxation. To achieve this target the revenue recycling data were converted to shares of revenue received and the shares were set to sum to 1, ensuring that tax receipts equal revenue recycling payments.

All three data sets were obtained in the form of annual time series covering the period 1994-2004. Gaps in the time series (for example in 2004) were estimated using linear interpolation based on projections of fuel use and Cambridge Econometrics' custom software.

Standardised units were used to store the data

The main unit of energy data in E3ME is thousands of tonnes of oil equivalent (th toe) and the economic variables are stored and calculated in millions of euros (tax data is held at current prices, then deflators used to obtain 2000-based series). The units chosen for the COMETR classifications are consistent with this, namely being:

Tax rates are held in euros / th toe.

Tax revenues are held in millions of euros.

Revenue Recycling is stored as shares and used to make changes to other taxes in millions of euros or investment (millions of 2000-based euros).

The main conversion factors used in the data processing

In cases where provided data were in national currency, the exchange rates on E3ME's economic time series databank were used to convert the data to euros.

These were the main conversion factors used for the energy classifications:

1 toe = 41.868GJ

1 toe = 11.63 MWh

1 tonne of oil = 1192 litres

1 tonne of petrol = 1362 litres

1 tonne of diesel = 1203 litres

Coal produces 25.4GJ / tonne

Oil produces 43.5GJ / tonne

Gas produces 35.6MJ / CUM

Petrol produces 44.8GJ / tonne

Diesel produces 43.3GJ / tonne

4.3 Software Inputs

Several different software packages were used

The data were received in a single Microsoft Excel spreadsheet.

Data processing is done using the Ox software package (see http://www.doornik.com/products.html#Ox). Ox is a flexible matrix-based software package that is similar to C in construct. Ox was used to read in raw data from the spreadsheets, process it, and save it to the E3ME databanks. There is also some interaction between Ox and Visual Basic in accessing the spreadsheet data efficiently and Cambridge Econometrics has its own library of custom Ox software to aid with the processing.

E3ME is programmed in Fortran and controlled by the IDIOM software package. E3ME's direct-access databanks are Fortran-based, but can also be accessed by Ox.

4.4 Processing the Individual Countries

Introduction

This section outlines the main steps and assumptions made in order to process the data for the individual regions as accurately as possible. All data were converted into the units given above using the converters described above. The data for tax rates were usually available, so it was not necessary to make many assumptions during the processing. However, this was not generally the case with revenues and revenue recycling methods. Much of this work drew from the analysis in DL1.2.

Denmark

Denmark is different from the other regions in that it makes a clear distinction between "light" and "heavy" industry and charges different tax rates to each one. This poses a problem for models such as E3ME that expect a single value. The current methodology counts all industry as heavy, but it is not clear if this is the best approach or not.

The tax revenues for Denmark are split between energy and CO2 taxes. Although the two are eventually aggregated this is useful for allocating between fuels and sectors. The energy tax is split by fuel and is not applied to industry (except motor fuels) so this part is straight-forward (fuels were shared out assuming that exemptions are equal for households and industry). The CO2 taxes were slightly more problematic in that only a national total was available and so these had to be split between households and industry, and also between the different fuel types. With no other information available the sharing was done using fuel tax * fuel uses, ie the exemptions are the same across households and users. It is unfortunate that no additional information was available to allow this assumption to be relaxed.

Existing taxes that existed before ETR commenced in 1992 were not included in the analysis. Existing taxes were defined as ones that existed in 1991 and were subtracted from the total tax rates to calculate just the ETR part. Likewise, a similar share of the revenues was removed and attributed to existing taxes.

Germany

Although the tax revenue data for Germany were relatively detailed compared to other regions, it did not make the distinction between industry and households. Therefore it was necessary to make the following assumptions:

For motor spirit and electricity, households have the same exemptions as industry.

For any other fuels households always pay the full rate.

As household consumption of fuels other than middle-distillates and electricity is very low, the second of these assumptions is not particularly important. However, particularly in the case of electricity, assuming the same exemptions are available for households and industry may not be realistic.

Revenue recycling in Germany was relatively complex compared to the other regions in that three main methods were used. Working on the basis that the cuts in social security contributions were shared equally between employers and employees the shares were calculated by dividing the extra investment by the total revenues, and equally splitting the rest between employers' and employees' social security contributions, so that the shares summed to 1.

NERI provided existing tax rates to subtract from the totals, allowing an analysis of just the ETR component of the tax.

Finland

Data for tax revenues were received as a hard copy and entered by hand into a spreadsheet. These data included seven fuels that were aggregated to the fuels in the CT classification. Interestingly no revenues for gas were included; it is possible that these data were part of light fuel oil but with no information to go on it was decided to add this separately by calculating tax rate * fuel use (ie assuming zero exemptions). As this is quite minor in Finland it should have little overall bearing on results.

The other major limitation with the Finnish data was that there was no distinction between revenues from industry and household. After reviewing the literature it was assumed that households had no exemptions and always paid the full charge. Exemptions for industry were then calculated as total revenue – (industry tax * industry fuel use).

Existing taxes in Finland (those that existed in 1996) were subtracted from the totals and were not considered to be part of the 1990s ETR.

There was no specific policy covering revenue recycling in Finland so it was assumed that all revenues from ETR were compensated for by reductions in income tax.

The only special industry exemption to take into account in Finland was that to very large firms, 10-12 in number, mainly in the paper and pulp industry[3]. However, the scale of the exemption was up to 85% and this is a very large sector in Finland so an effort was made to include this. According to the Finnish Forestries Industries Federation[4] the five largest firms made up 85% of turnover in the sector. Therefore it was assumed that the ten largest firms made up 90% of the sector and energy use. Given these assumptions, it seemed reasonable to ignore the relatively small threshold of €50,000 below which all tax is paid, and simply reduce payments from this sector by 100 * 0.85 * 0.9 %. Consequently the pulp and paper sector only paid 23.5% of the tax.

The Netherlands

Much of the processing for the tax rates in the Netherlands was fairly simple in nature, with an average tax rate calculated for heating oil from gas oil and kerosene. Excise duties were not counted as part of the ETR, and any taxes that existed before 1998 were not counted as part of the modelled ETR.

There were major difficulties in estimating industry tax rates and revenues for gas and electricity, however. Energy tax rates for these fuels in the Netherlands are dependent on the size of user (in terms of fuel consumption); in the case of households it was assumed that all users fell into the smallest category, but this was not a valid assumption for industry. After extensive searching, no relevant data were found for firm-size in terms of energy use; while it would have been possible to use the closest data (firm-size based on employment or turnover) there is no guarantee that this would have been any more accurate than using a single estimate (and this may also have introduced bias between sectors) so a single category was chosen. This was 50,000-10m kWh of electricity and 170,000-1m cubic metres of gas.

In the scenarios with no exemptions, the highest tax rates were used. These are normally the lowest band, so this is effectively assuming that there are no exemptions for households.

A further complication in processing the Netherlands is that the revenues are disaggregated into just two categories: energy tax and other environmental taxes. As there was no specific mention of exemptions on fuels with the simpler taxes (coal and oil) these revenues were assumed to be correct, and the more complex systems (gas and electricity) were scaled so that the revenues in E3ME matched the published total.

As there was no specific treatment of revenue recycling in the Dutch ETR, it was assumed that the alternative was higher direct income taxes.

Sweden

The approach for Sweden was very different to the other regions. Statistics Sweden publishes a very detailed set of revenues from environmental taxes, disaggregated by NACE 2-digit sector. It was decided to make use of these data, rather than rely on E3ME to estimate the sectoral revenues. This means that a separate rate of exemption will be available for each industry. This does assume, however, that the industry

[3] The Use of Economic Instruments in Nordic and Baltic Environmental Policy 2001-2005, http://www.norden.org/pub/sk/showpub.asp?pubnr=2006:525

[4] http://english.forestindustries.fi/

exemptions are independent of the fuel mix to that industry – ie the same *exemptions* will apply to coal, gas and renewable energy (although this of course does not mean that the actual tax rates do not vary by fuel type).

As a result of this, the tax revenue data for Sweden was stored as a 19 x 11 matrix (19 fuel users and 11 years) rather than a 12 x 11 matrix (the 12 CT categories and 11 years). E3ME required specific adjustments to cope with this.

Finally, the time series for Swedish tax revenues were extrapolated to include 2003-04. This was done assuming a linear relationship between the tax revenues and the given tax rates multiplied by projected fuel use.

With no further information it was assumed that all revenues from ETR were recycled in the form of reduced income taxes.

The UK

The climate change levy (CCL) rates were easily obtainable in the UK, but the revenues from the tax are only available as an aggregate for the UK. Individual industries that do not pay the CCL are exempted from the tax during the modelling stage (based on CE's fuel user classification) but the assumption is that exemptions are equal across fuels, so the revenues are allocated to fuels in line with total consumption of that fuel.

By using the data for revenues, the negotiated agreements are taken into account. However, the scenarios principally look at the price effects of the CCL and not energy savings made in response to the negotiated agreements; however, the announcement effect on energy demand by other final users has been taken into account. Analysis in other COMETR work packages suggests these Negotiated Agreement effects are not insignificant, so results published here may be understating the overall drop in fuel demand and emissions resulting from the CCL.

As the CCL is a completely new tax in the UK, there was no issue about what counted as part of the 1990s ETR and what was already in place. Revenue recycling was assumed to have occurred completely through the effects of reducing employers' social security contributions.

Slovenia

Although the CO2 tax in Slovenia was not, strictly speaking, part of an ETR it has been included in the Baseline scenario to give an example of environmental taxation in the New Member States. For the purpose of the modelling, it was assumed that the revenues were recycled through reductions in direct income taxes.

It was very difficult to define the CO2 tax in Slovenia with environmental taxes often being bundled with other taxes and different data sources giving conflicting stories. Following consultation with IEEP it was decided that only a tax on natural gas consumption should be included. With no data for revenues, it was necessary to assume zero exemptions in all the scenarios, and estimate revenues as tax rates multiplied by fuel use.

The CO2 tax was not applied to the power generation sector so it was excluded in the scenarios.

TABLE 4.3: REVENUE RECYCLING BY COUNTRY (Million €)

		1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Denmark	Income Tax	0	0	0	0	0	0	0	0	0	0	0
	Social Security Contributions	271	615	943	1032	1311	1702	1820	1898	2044	2134	2140
	Investment	0	0	8	13	17	28	26	13	0	0	0
Germany	Income Tax	0	0	0	0	0	1952	4002	5698	6951	9009	9181
	Social Security Contributions	0	0	0	0	0	1952	4002	5698	6951	9009	9181
	Investment	0	0	0	0	0	201	197	304	183	182	204
Finland	Income Tax	0	0	0	373	614	700	685	721	722	895	894
	Social Security Contributions	0	0	0	0	0	0	0	0	0	0	0
	Investment	0	0	0	0	0	0	0	0	0	0	0
Sweden	Income Tax	-124	-50	349	657	1550	1570	1852	1741	1992	2395	2585
	Social Security Contributions	0	0	0	0	0	0	0	0	0	0	0
	Investment	0	0	0	0	0	0	0	0	0	0	0
United Kingdom	Income Tax	0	0	0	0	0	0	0	0	0	0	0
	Social Security Contributions	0	0	0	0	0	0	0	540	1372	1134	1201
	Investment	0	0	0	0	0	0	0	0	0	0	0
Slovenia	Income Tax	0	0	0	0	0	16	43	57	46	45	45
	Social Security Contributions	0	0	0	0	0	0	0	0	0	0	0
	Investment	0	0	0	0	0	0	0	0	0	0	0

4.5 Revenue Recycling Methods

Table 4.3 above illustrates the mechanisms used for recycling revenue. Section 3.5 describes these methods in more detail and outlines the expected results in each case.

4.6 Key Assumptions Made by Cambridge Econometrics

Modelling assumptions

Unless otherwise stated, all the modelling follows the same assumptions of the E3ME model. These are documented in the model manual, which is available online at http://www.camecon-e3memanual.com/.

In addition, the following assumptions have been made:

All of the taxes are revenue-neutral. Although there are cases where the ETRs are not designed or intended to be revenue neutral, this has been imposed in the modelling so that the results indicate the effects of a shift in the tax burden rather than an overall increase or decrease in the tax burden. In cases where the data did not support this, shares were used to scale the revenue recycling to match the tax revenues. In cases where there was no clear method of revenue recycling (Finland and Sweden) it was assumed that environmental taxes were an alternative to higher direct labour taxes.

Tax rates and rates of economic activity in the non-ETR regions and outside the EU are assumed to remain constant.

Data assumptions

This section summarises the main assumptions made during the data processing in order to get a complete data set, and reflect our attempts to make best use of the information available.

Where detailed tax revenues have been missing, typically the aggregates have been shared out using shares of (fuel tax * fuel use), assuming exemptions are similar across fuels or industry. If the literature suggests that there are no exemptions in a particular group then this total is entered into the data and the remainder of the aggregate tax receipts are shared out.

Revenue recycling in Finland and Sweden is assumed to be through a reduction in income taxes.

Where time series did not cover all of the period 1994-2004, linear interpolation based on fuel use was used to estimate missing values. Tax rates were assumed to remain constant when no information was available.

Tax rates are assumed to remain constant in current prices over the forecast period.

Table 4.4 shows that ETR as a percentage of GPD in 2004 is less than 1.1% for all the ETR countries. There are noticeable differences between the ETR countries; in the UK, the ETR accounts for just 0.07% of GDP, compared to 1.08% in Denmark, 0.92% in Sweden and 0.84% in Germany.

TABLE 4.4: ETR AS A PERCENTAGE OF GDP, 2004

	DK	DE	NL	FI	SE	UK	SI
ETR €m	2140	18547	2287	894	2585	1200	45
GDP €m	197222	2207200	489854	151935	281124	1733603	26232
ETR as a % GDP	1.08	0.84	0.47	0.59	0.92	0.07	0.17

5 Specification of ETR Scenarios

This chapter first discusses the main concepts underlying environmental tax reforms introduced by some EU member countries (Denmark, Finland, Germany, the Netherlands, Sweden, and the UK) in the 1990s and the objectives of policymakers in making such changes. In Slovenia, the CO2 tax, although not strictly part of an ETR, has been included in the Baseline scenario to give an example of environmental taxation in the New Member States. The scenarios that were constructed for the modelling based on E3ME are then outlined.

5.1 Features of Environmental Tax Reforms

The notion of 'environmental tax reform' (ETR)[5] typically involves the modification of the national tax system to move the burden of taxes from conventional taxes, for example those imposed on labour and capital, to environmentally-related activities, such as taxes levied on resource use, especially energy use, or environmental pollution. The objective of a tax-shifting programme is to ensure that tax burdens are distributed more 'equitably' from an environmental and sustainability standpoint. Revenue neutrality, defined as a reduction in other taxes to offset an increase in revenues arising from the introduction of an environmental tax, has often been a motivating factor to ensure that there is no change in the overall tax burden at the national level. The implementation of a revenue-neutrality policy is designed to ensure that the tax burden falls more on 'bads' than on 'goods' by ensuring that price signals, as a result of the introduction of ETR, give an incentive to households and industries to alter behaviour. This is complicated by interaction with effects of other taxes.

The environmental tax programmes differ across the six EU member states that have implemented ETRs through the industries targeted and the revenue recycling mechanisms. The green tax reform changes not only tax rates, but because of change in input demands, it also changes the tax base. The effects of the green tax reforms on the tax base are short and long-term: the short-term effect comes from an immediate change in the composition of input costs.

The green tax reform can affect one or more of the following economic sectors: power generation, industry, households and transport. The taxes that increase under an ETR usually include energy taxes and other environmental taxes. Some ETRs may also involve the creation of a new tax that replaces an old one (and which does not necessarily have the same tax base).

5.2 Purpose of an ETR

ETR is intended to shift taxation away from beneficial activities, such as employment, towards damaging activities such as pollution. The idea is to implement specific taxes to encourage households and industries to behave in a

[5] These features of ETRs that emerged from the analysis undertaken in Work Package 1 are discussed in DL1.3 Part 2 'An Overview of Environmental Tax Reforms in EU Member States' produced by NERI for the Partners' meeting 6-7 June 2006.

way which is environmentally sustainable. The revenues thereby generated are used to reduce burdensome taxes to complete the ETR.

This 'recycling mechanism' may take effect through:

- Direct taxes (income tax, corporation tax);
- Social security contributions
  - paid by employers;
  - paid by employees;
- Other measures
  - Support schemes for investment expenditure (and depreciation); and
  - Benefits or other compensatory measures.

In certain European countries, the ETR has also included tax provisions tailored towards certain industry sectors (particularly those which are energy-intensive) to induce a more energy-efficient consumption profile and thus reduce the environmental impacts of their economic activities.

An ETR can, in principle, provide complete tax exemptions for economic sectors or reduced tax rates for different energy fuels and economic sectors in combination with some form of negotiated agreements with targets to improve energy efficiency or carbon emissions. Tax ceilings may also be established to limit the total tax burden faced by individual companies.

5.3 Outline of ETR Scenarios/Cases

The results discussed in Chapter 7 consider the various components of the green tax reform packages described above. The following scenarios were generated by E3ME over the period 1994 to 2012 so that the projection period includes Phase 2 of the EU ETS:

- the Reference Case (R) which is a counterfactual projection without the ETR, but including current and expected developments in the EU economy, eg the EU ETS
- the Baseline Case[6] (B) which is an endogenous solution of E3ME over the period 1994-2012. This scenario includes the ETR in each Member State covered by the project, exemptions or special treatment for the industries most affected and the compensating reduction in another tax. This scenario is calibrated closely to the observed outcome through using historical data which include the effects of ETR implementation
- the tax with no exemptions and special treatment case (E) but with compensating measures

[6] The historical part of the baseline solution, used for ex-post analysis, covers the period 1994-2002 (or 2003 where the data were available at the start of the project in December 2004). The forecast component of the baseline solution to 2012, used for the ex-ante analysis, is derived from a combination of DG TRENS 'Energy and Transport Trends to 2030' and IEA's energy price assumptions given in the 'World Energy Outlook 2005' (see Chapter 7 section 1.1 for details).

TABLE 5.1: COMETR SCENARIOS

Scenario	ETR	Revenue Recycling	Exemptions
1 Reference (R)	No	No	N/A
2 Baseline (B)	Yes	Yes	Yes
3 Exemptions (E)	Yes	Yes	No
4 Compensation (C)	No	Yes	N/A

- the case with a compensating reduction in another tax on its own (C) Usually, a scenario of this type would look at the effects of the taxes without the revenue recycling. Here it is done the other way round because the ETRs are subtracted from the baseline rather than added. This scenario therefore subtracts the energy and carbon taxes (so there is no ETR) from the baseline but does not change the compensating measure from the baseline (so we do have revenue recycling as in the baseline). To do the opposite (a scenario with the energy and carbon taxes but not the compensating measures) would be difficult as, without changing the energy and carbon taxes it is not obvious how large the compensating measure should be. By comparing scenario C to the baseline we can isolate the effects of the energy and carbon taxes. By comparing scenario C to the reference case we are isolating the effects of the compensating measures

These scenarios allow the ETR to be decomposed country by country into three components: the full tax, the exemptions, the compensation via recycling. The price and non-price competitiveness effects are considered to see whether any inferences can be drawn about to the Porter hypothesis (ie, 'improved performance in the ETR sectors will level out the impact of the increased tax level', see pp 4-5 of COMETR Annex I – Description of the work).

The results are discussed in Chapter 7 for each Member State with an ETR and some comparisons are made relating to the impact of ETR on economic activity in the ETR and non-ETR countries in the EU. An overview of the ETR components analysed under each scenario is provided in Table 5.1.

These scenarios are also analysed sector by sector to consider the impact of the ETRs on competitiveness in the energy-intensive sectors, which are the focus of the study. The results of the above scenarios are then used to evaluate the sector impact of industrial-specific taxes, exemptions and/or special treatments on other industries and the economy as a whole. By calculating the overall size of tax shifts (eg, in percentage of GDP) paid by/recycled to industry and households, the net 'winners' and 'losers' of the ETRs can be identified. The aggregate of the individual industry-specific impacts is equivalent to the effects in the Baseline scenario in relation to the Reference Case.

In addition to the *five* parent NACE 2 E3ME sectors (ie 15: Food and Food Products; 21: Pulp, paper and paper products; 24: Chemicals and chemical products; 26: Non-metallic mineral products; 27: Basic metals) that were treated in detail at NACE 3 level for *eight* sectors (ie 15.1: Meat and meat products; 21.2: Paper and paperboard products; 24.1: Basic chemicals and 24.4: Pharmaceuticals; 26.1: Glass and glass products and 26.5: Cement, Lime and plaster; 27.1-27.3:

Ferrous metals and 27.4: Non-ferrous metals) in the bottom-up analysis undertaken in Work Package 3, the following broad sectors were also considered:

- Power generation
- Energy-intensive industries
- Other industries
- Transport
- Households

5.4 Developing the Assumptions for the scenarios

The paper 'Overview of Environmental Tax Reforms in EU member states' by Stefan Speck (DL 1.3:'Reviewed, Revised, and Condensed Research Report to provide input for DL 7.2: Part B) describes in detail the various ETR considered in the project.

These details have been translated into assumptions, rates of tax and special treatments in E3ME and the processing required is described in Chapter 4, Appendix D gives details of full set of tables for the tax rates, revenues and revenue recycling methods that were adopted in the E3ME modelling, discussed in Chapter 7.

6 Estimation of the E3ME Competitiveness Effects

6.1 The Economic Theory behind the Estimation

Introduction

This section describes the estimated equations within E3ME that are most relevant to competitiveness and the final results. The aim in the specification and estimation is for a coherent economic explanation, with consistent long-term properties, robustness in equation behaviour and parsimony in their specification. In general any aggregate European equations will follow their regional (member country) counterparts.

The main endogenous variables in E3ME are determined from functions estimated on historical data for European energy use and the European economies. There are a relatively small number of variables (for example, energy demand by fuel user by region, matrix FR0) for which stochastic functions are estimated; around 22 in all. However these variables may well be disaggregated in two dimensions (there are 19 fuel users and 27 regions) and IDIOM allows up to ten alternative functional forms to explain each disaggregated category.

The econometric techniques used to specify the functional form of the equations are the concepts of cointegration and error-correction methodology, particularly as promoted by Engle and Granger (1987) and Hendry et al (1984).

In brief, the process involves two stages. The first stage is a levels relationship, whereby an attempt is made to identify the existence of a cointegrating relationship between the chosen variables, selected on the basis of economic theory and a priori reasoning, eg for employment demand the list of variables contains real output, real wage costs, hours-worked, a composite real energy price and the two measures of technological progress.

If a cointegrating relationship exists, then the second-stage regression is known as the error-correction representation, and involves a dynamic, first-difference, regression of all the variables from the first-stage, along with lags of the dependent variable, lagged differences of the exogenous variables, and the error-correction term (the lagged residual from the first stage regression). Due to limitations of data size, however, only one lag of each variable is included in the second-stage.

Stationarity tests on the residual from the levels equation are performed to check whether a cointegrating set is obtained. Due to the size of the model, the equations are estimated individually rather than through a cointegrating VAR. For both regressions, the estimation technique used is instrumental variables, principally because of the simultaneous nature of many of the relationships, eg wage, employment and price determination.

6.2 Estimated Competitiveness Effects in the COMETR sectors

Definition of the sectors

Five sectors were chosen at the NACE 2-digit level, in line with the other COMETR work packages. One of these sectors covers two E3ME sectors (the E3ME Pharmaceuticals and Chemicals nes sectors make up NACE code 24); so both of these sectors were also included. The full list is shown in Table 6.1.

TABLE 6.1: SECTOR CLASSIFICATIONS

NACE 2 digit code	Full Description	E3ME sectors	E3ME Description
15	Manufacture of food and food products	5	Food, Drink and Tobacco
21	Manufacture of pulp, paper and paper products	7	Wood and Paper
24	Manufacture of chemicals and chemical products	10	Pharmaceuticals
		11	Chemicals nes
26	Manufacture of other non-metallic mineral products	13	Non-Metallic Mineral Products
27	Manufacture of basic metals	14	Basic Metals

Definition of the regions

The six regions that followed a path of environmental tax reform in the 1990s are:

- Denmark
- Germany
- The Netherlands
- Finland
- Sweden
- The UK

For Slovenia, the CO2 tax, although not strictly part of an ETR, has been included in the Baseline scenario to give an example of environmental taxation in the New Member States.

Estimating the direct effects of ETR

The following discussion analyses the key price and non-price competitiveness effects estimated for each of the equations for each region and sector. These parameters are central to modelling the direct effects of ETR in the final scenarios. Results are presented for the price and non-price qualitative effects as EU-25 averages. Typically the dependent and explanatory variables in the E3ME equations are expressed in logarithmic form, so the figures in the following tables may be interpreted as elasticities. The estimation period is 1970-2002.

Aggregate energy demand

- Price Effects

In E3ME, the price variable for aggregate energy demand is formed by taking the average of the twelve different fuel types. The parameter estimates for the price variables are less than or equal to 0, indicating that an increase in energy prices reduces energy demand. Some long-term price elasticities are restricted in E3ME to match results from previous research. The highest average long-term estimated price elasticity (which would indicate a long-term switching from fuel to other inputs) is in paper & pulp (around a 4-5% fall in demand for a 10% rise in prices). While iron & steel also has a relatively high price elasticity, the elasticity in paper & pulp is roughly double the expected effect in the other COMETR industries. This trend is particularly well demonstrated in Germany, where energy demand from iron & steel falls by 4% for a 10% rise in prices, and by 6.5% in paper and pulp, but effects are smaller in other sectors.

Among the COMETR regions, the effects are largest in Finland, where energy demand in all the sectors, except iron & steel, shows much higher price sensitivity than the EU average.

The estimated short-term price elasticities are generally smaller than the long-run estimates, but paper & pulp remains the industry where demand is most sensitive to price changes.

- Non-price effects

The indicator used to demonstrate technical progress in the fuel-demand equation is directly related to current investment demand, rather than the accumulated investment used in the other equations. The relationship between investment and energy demand in these industries is assumed to be negative, ie improvements in efficiency will curb demand for energy, all other things being equal. A higher (negative) long-term parameter indicates a potential for energy savings in the industry through efficiency gains in the long run. Apart from non-metallic mineral products (where there is very little implied change in energy demand) results are fairly similar across industries and region, with a 10% increase in investment causing a 1-2% fall in long-term energy demand. The short-run effects are often found to be insignificant, reflecting the time it takes to install and use new equipment, and have therefore been removed from the equation.

Employment

- Price (wage) effects

The price effect in E3ME's employment equation is in the form of wage rates. Higher wages will reduce employment in all the sectors. A high long-term parameter would generally indicate an opportunity to replace labour inputs with capital or other inputs. Of the six examined sectors, by far the most sensitive to wage costs in the long run is basic metals, where EU employment would fall by 7% for a 10% increase in wages, and in Germany and the UK employment in this industry would fall by nearly 13%. Although basic metals is relatively small in most European countries, this result shows a flexibility between labour and other inputs, and we would expect to see relatively large increases in long-term employment in basic metals in scenarios where labour taxes are cut. In the other sectors on average we see predicted falls in employment of 2-4% for a 10% increase in wages.

As expected, the short-term price-elasticities for demand for labour are smaller than the long-term estimates (except for wood and paper) and in many regions are non-significant. In most sectors we see a larger short-term reaction of employment levels to wage rates in the UK compared to the other regions, reflecting a greater degree of flexibility in the labour market.

- Non-price effects

The parameters for employment in relation to technical progress may be positive or negative in the short term, as progress may be labour-saving or may increase demand for labour. E3ME makes the distinction between ICT and non-ICT investment and it is clear from the results that in the energy-intensive sectors examined, ICT investment reduces the long-term demand for labour but non-ICT investment generally increases labour demand. It should also be noted, however, that the positive effects from non-ICT investment generally outweigh the negative effects of ICT investment but, apart from basic metals, the combined effect is quite small.

The effects of technical progress are fairly consistent across the COMETR regions, and that is probably to be expected given spillover effects; and the short-term parameter estimates are often insignificant. The average parameter estimates in Appendix B reflect the summation of positive and negative effects across regions, but there was no discernible pattern in the results.

Export volumes

- Price effects

E3ME makes the distinction between exports to other EU member states (QIX) and to regions outside the EU (QEX). The price effects are assumed to be negative to all destinations in the long and short term (ie an increase in export prices would cause a decrease in export volumes). We would expect price effects to be greater where there is a higher degree of competition. This is demonstrated in E3ME by the much higher price elasticities on exports to the EU single market: in the food, pharmaceuticals, non-metallic minerals products and basic metals industries, a 10% rise in prices would lead to a fall in export volumes to other EU states by 3% or more, but only a very small fall in exports to other destinations. Results are less clear in the wood and chemicals industries, possibly because European export production in these sectors is dominated by a small group of countries.

- Non-price effects

The quality of export goods is measured through the two technical progress indicators in E3ME. These effects are assumed to be positive, ie there will be a higher demand for a better-quality product, all other things being equal. The long-term parameters show two clear trends. First, investment in ICT has a more beneficial effect on export volumes than non-ICT investment (to all destinations). Second, effects are generally greater on trade with EU partners, reflecting the greater level of competition within Europe. The average size of the estimated parameters indicates the importance of technical progress as a driver of long-term export growth. For example, a 10% increase in the ICT technology index would increase food and pharmaceuticals exports by around 7% and exports from the other COMETR industries would increase by around 4%. Results with the non-ICT index are less clear, but, on average exports will increase by around 2% for a 10% increase in the index. This is, however, to assume that all other factors remain constant. In particular, it is likely that an increase in quality of goods would be matched by an increase in prices to cover the cost of investment (see results from the export price equation below).

Import volumes

- Price effects

As with the treatment of exports, E3ME splits imports into those from other EU member states (QIM) and those from outside the EU (QEM). However, there is very little difference between the price elasticities estimated in the two equations, either in the short or long-term equations. This makes intuitive sense, as import volumes will be determined by the difference between import prices and domestic prices and not by the product's country of origin. The parameter estimates for external trade are important, however, in determining the effects of import tariffs. The results show that imports of chemicals and pharmaceuticals are much less sensitive to price than the other industries (a 10% fall in import prices would lead to just a 1% increase in these sectors, compared to a 4-6% increase in the other sectors). The average estimated elasticity for the food industry is close to 0.5, indicating that tariffs do offer some long-term protection to the industry. Results for agriculture are similar.

Results for the short-term parameters are similar to the long-term equations, although imports of chemicals and pharmaceuticals are more sensitive to short-term price changes. The most likely explanation for this is that the data reflect the purchase and storage of commoditised goods in the chemicals and pharmaceuticals industries, so that there can be a relatively large reaction to short-term price changes, even though the underlying production function remains unchanged.

- Non-Price effects

The two technology indicators are present in the import volume equations. The technology indicators are for the importing country and therefore the parameter coefficients are assumed to be negative (ie a higher quality domestic product will reduce import demand). As with the price variables, there is little difference between the effects of goods imported from inside and outside the EU. Surprisingly, given the results for exports, the non-ICT investment index generally has a greater effect than the ICT index. However, this mainly reflects the fact that most investment in these industries is in non-ICT products, so a 10% increase in investment is from a much higher base for non-ICT investment, and consequently can be expected to have a greater effect on product quality. This does not imply that investment should be switched to non-ICT products; indeed, given the results for exports, we would expect the opposite to apply.

Export prices

- Non-Price effects

The relationship between technical progress and trade prices can be difficult to model, and a lack of available data often makes results less reliable than we would like. Many of the parameter estimates are found to be statistically insignificant and have been removed from the equations. On average, in the energy-intensive sectors, a 10% increase in the technical-progress indicators causes a 1-2% increase in export prices. Export prices in basic metals and non-metallic mineral products seem to react more to quality increases, but as the COMETR sectors are not associated with high levels of investment (with the exception of pharmaceuticals), results may be misleading.

Import prices

- Non-Price effects

Results for import prices are of a similar magnitude to those for export prices, with a 10% rise in the indices causing a 1-2% fall in import prices. There is little difference between the ICT and non-ICT indices in the long term, although an increase in non-ICT investment typically causes a much larger immediate price increase. This probably reflects the fact that most of the investment in these sectors is in non-ICT equipment.

Domestic prices

- Non-Price effects

The non-price competitiveness effects in the domestic-price equations are measured by the two technical-progress indicators. The domestic-price equations show some clear trends in the effects of technical progress and product quality on prices. In the long term, a 10% increase in the technical-progress indices will lead to a price increase of 2-3%. The effects are weaker in non-metallic mineral products (1%) and wood & paper (1%), however. Although there are some differences between the effects of ICT and non-ICT investment, these do not appear to be significant overall.

In the short-term equations, prices are more sensitive to technical progress. This makes intuitive sense in that businesses will be looking to recoup investment costs through charging a premium. This is particularly true in pharmaceuticals, where research costs must be covered before patents expire, but on average, the increase in costs from a 10% rise in the technical indices is around 3-4%. As is the case with the long-term parameter estimates, there does not seem to be much difference between the ICT and non-ICT effects. The exception is Finland, where increasing ICT investment has almost no effect on short-term prices.

6.3 Estimated Competitiveness Effects in other Sectors and Regions

Measuring the indirect effects

The tables in Appendix B display E3ME estimation results split by broad sector and by region, and show a weighted average for the 27 E3ME41 regions. These are important in the context of the COMETR scenario analysis in that they determine the level of interaction between the examined industries and other industries (through the input-output tables) and regions (through the trade equations). The indirect effects can be as large as the direct effects; so these results are a key feature of the modelling and their inclusion offers a significant advantage over many simpler approaches.

Price effects

The results from the employment equations show that there is little difference between the sectors when considering the long-term effects of wages on employment. On average, a 10% increase in wages will cause a 4% fall in employment. The exception is in market services, where a 10% increase in wages would cause a 2.5% fall in employment. This reflects a lower degree of possible substitution between labour and other inputs in market services than, say, in manufacturing or construction; in particular distribution, retail and communications had small parameter values. Employment in the UK is most sensitive to short-term changes in wage rates, but the Netherlands, Ireland and Finland also have higher parameter values.

In the trade equations it is striking how imports are much more price-sensitive than exports, both in the long run and the short run. This is true for manufacturing and services and could indicate greater market competition in home markets than abroad. For example, there is very little long-term price reaction in exports outside the EU, but there is for exports to other EU regions (-0.1 for manufacturing and -0.2 for services).

In the equations for aggregate energy demand households are much more price-sensitive to changes in fuel prices in the short term. Transport is the least sensitive. This makes intuitive sense, as there are many ways in which households can save energy relatively easily but the transport sector requires large investments to make energy savings. The long-term results also support this theory: the transport sector is the most sensitive to changes in price, as vehicles are adapted to alternative fuels and more efficient methods, but households are much less willing to change. In fact, the short-term price effects on households are greater than the long-term effects, indicating that households react to changes in price, but do not change their underlying behaviour.

Non-price effects

Non-price competitiveness in E3ME's trade equations is measured through the technical progress indicators. If the technical progress indicators rise, so does the quality of domestically-produced goods. Therefore, under these conditions we would expect exports to increase and imports to fall. This is true for all the traded sectors, but in the short run the estimation results show the effects to be much greater for services than for manufacturing. In the long term, the effects are roughly equal. A likely explanation for this is that it takes longer for manufacturing industries to adapt their production processes to make use of technological developments, so there is less immediate reaction. In the long-term results, there is a much larger effect on exports from ICT investment than non-ICT investment. These effects are particularly strong in exports to other EU regions.

The long-run non-price effects in the aggregate fuel demand equation are harder to quantify. The direct effects of industry investment on fuel demand are very small and initially appear to be greater in the short run than in the long run, a counter-intuitive result. However, this is because most of the effects of technical progress are transmitted through another variable in the equation, ZRDM. This variable represents aggregate EU R&D in machinery and, as one would expect from a spillover variable, this is particularly influential in the long-run equations.

7 The Effects of Selected EU ETRs, using E3ME, 1994-2012

This section describes how the Baseline was constructed, and discusses the simulation results from the COMETR scenarios. We start by looking at the Baseline solution, and taking an overview of the results from the countries that pursued ETR in the 1990s, and then discuss the individual countries in more detail. Then we look at the competitiveness effects on individual energy intensive sectors, and the effects of the exemptions from the taxes that are available in some countries. Finally we consider the effects of the 1990s tax reforms across the rest of Europe.

A full set of tables outlining the tax rates and revenues used to define the scenarios can be found in Appendix D and the full set of results tables from the simulation runs can be found in Appendix E.

All the charts in this chapter compare results against the Reference case for ease of interpretation, ie when results for the Baseline case are shown as a percentage difference, this means the percentage difference caused by the combination of the environmental taxes and the revenue recycling.

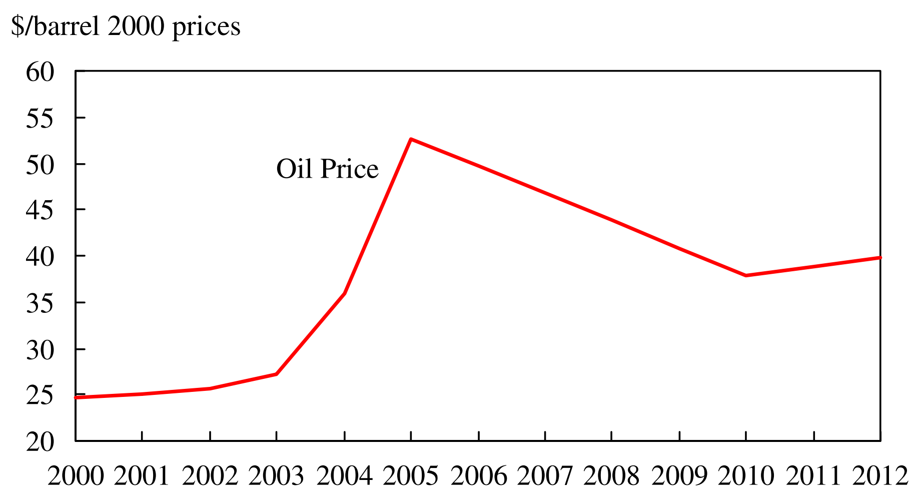
7.1 Creating the Baseline Solution

Data inputs

The Baseline solution for COMETR is an endogenous model solution of E3ME that fully covers the period 1994-2012 annually. The Baseline solution is calibrated to be consistent with a combination of historical data and forecast.

The historical part of the Baseline solution, which is used for the ex-post analysis of 1994-2002 (or 2003 where the data were available at the start of the project) comes from E3ME's historical databanks. The main sources for these are the OECD, Eurostat and the IEA. These data include the effects of ETR in the 1990s, and any accompanying exemptions and revenue recycling methods.

CHART 7.1: OIL PRICE ASSUMPTION



Source(s) : CE.

The forecast part of the Baseline solution, which is used for the ex-ante analysis, is derived from a combination of DG TREN's *Energy and Transport Trends to 2030* (published by the EEA), and the IEA's *Energy Price Assumptions*. While the DG TREN forecast provided a consistent set of forecasts for energy demand and economic activity, the assumptions underlying the forecast (namely energy prices, world growth and the ETS) were outdated. To compensate for this, E3ME was calibrated to meet the DG TREN forecast, and then solved again with a different set of assumptions for energy prices, which take into account the shock to oil prices over 2004-05 (see Chart 7.1), and the ETS allowance price (see Chart 7.2). The energy price assumptions are important because they set the ratio of environmental tax to total fuel cost (ie the difference between the scenarios) which determines the scale of the effects.

However, it was not possible to obtain more recent forecasts for world GDP growth that were consistent with the other inputs, so the EEA numbers were used.

Calibrating to a published forecast

E3ME uses a system of multiplicative residual values to calibrate to a published forecast. The method for doing this is fairly straight forward: First, the model is solved over the historical and projection periods, but the equation results are fixed to the published values using a scaling factor. These scaling factors are then saved as residual values to the E3ME databanks and when the model is run again, these are used to obtain an endogenous solution that matches the original forecast.

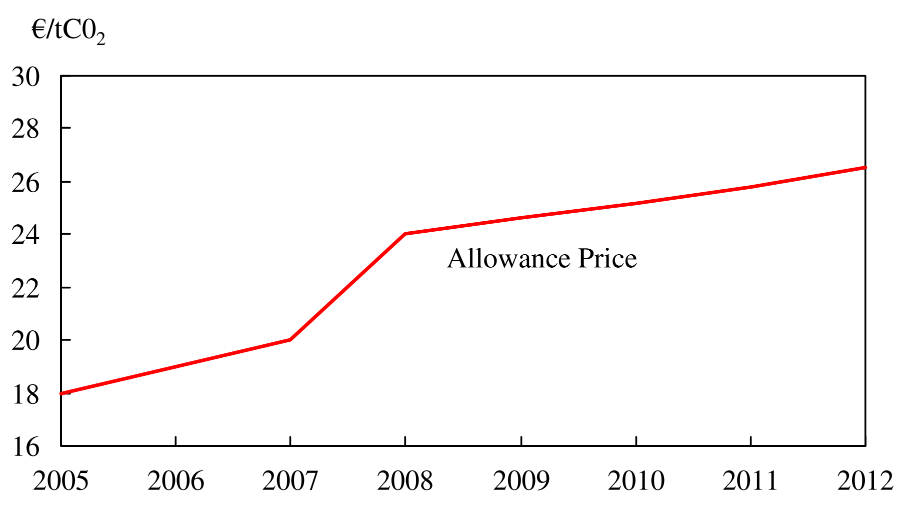
At this stage it is also necessary to remove equations from the model that are likely to cause instability within the solution; these are typically small sectors with unreliable or negative data, or with structural breaks in the time series.

The COMETR project is the first time that E3ME has been solved endogenously over its historical period.

7.2 Model Results: Overall Effects of ETR

This section compares the results for the Baseline case against the Reference case. In summary, this illustrates the difference between what did happen and what would

CHART 7.2: NOMINAL EU ETS ALLOWANCE PRICE PROJECTION



Source(s) : CE.

have happened had there been no ETR (with both cases projected to 2012). The exception to this is that revenue neutrality is assumed in each case through the revenue recycling mechanisms (see Chapter 3). Exemptions, non-payments and negotiated agreements are included as accurately as possible as they happened, subject to the total revenues matching the published figures in each case. Therefore the data used for this analysis are the tax *revenues* collected by the COMETR partners. Effective tax rates are determined by the ratio of revenues divided by fuel use. The taxes are not assumed to have any effect other than to increase energy prices (eg there are no extra awareness effects), with the exception of the CCL announcement effect in the UK. See Chapter 4 for more details of the data processing and the assumptions made for each region.

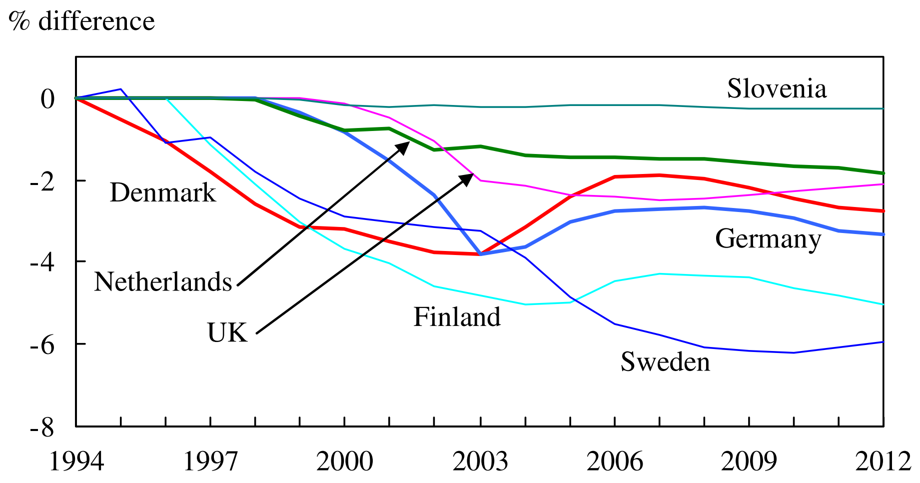
Energy demand

As the taxes included in the analysis increased fuel prices, we would expect the primary effect to be a reduction in the demand for energy. The scale of the reduction will depend on the tax rates, on how they are applied to the various fuels and fuel user groups, on how easy it is for fuel users to substitute between the different fuel types and non-fuel inputs, and on the scale of the secondary effects from resulting changes in economic activity.

All the six regions show a reduction in fuel demand from the ETR (see Chart 7.3). In most cases the reduction in fuel demand was in the region of 4%, although it was slightly larger in Sweden and Finland than the other regions.

A key feature of the results is the recovery in fuel demand in several of the examined countries over 2004-05 in the Baseline case relative to the Reference case, due to higher world energy prices, included in both the Baseline and Reference cases. In most of the ETRs, the environmental taxes were not raised in line with fuel prices (and in some cases may have been reduced), implying a reduction in the relative change in fuel prices. For example, a tax that doubled the price of oil for households in 2003 may only have increased it by 50% in 2005. Consequently the change in fuel demand becomes less in these years.

CHART 7.3: THE EFFECT OF ETR ON TOTAL FUEL DEMAND



Note(s) : % difference is the difference between the base case and the counterfactual reference case.

Source(s) : CE.

After 2004, the environmental taxes are assumed to increase in line with the consumer price index (not energy prices). Results after 2004 are therefore mainly a reflection of the changing energy prices, and the dynamic and lagged effects of the ETRs.

GHG emissions

We would expect to see a reduction in atmospheric emissions from lower fuel consumption, but total emissions will also depend on the relative consumption levels of each fuel type. For example, a tax system that encourages the use of coal is likely to produce higher emissions than one which encourages the use of natural gas or bio-fuels. E3ME includes explicit equations for fuel shares of hard coal, heavy oil, natural gas and electricity. Assumptions are made about the other fuel types linking them to the closest modelled alternative (eg other coal is linked to hard coal, crude oil to heavy oil). For middle distillates (petrol, diesel, etc) demand is linked to total fuel demand by that sector. The reason for this is that demand for these fuels is dominated by the transport sectors. These sectors do not generally use any other fuels, so fuel share equations are not required.

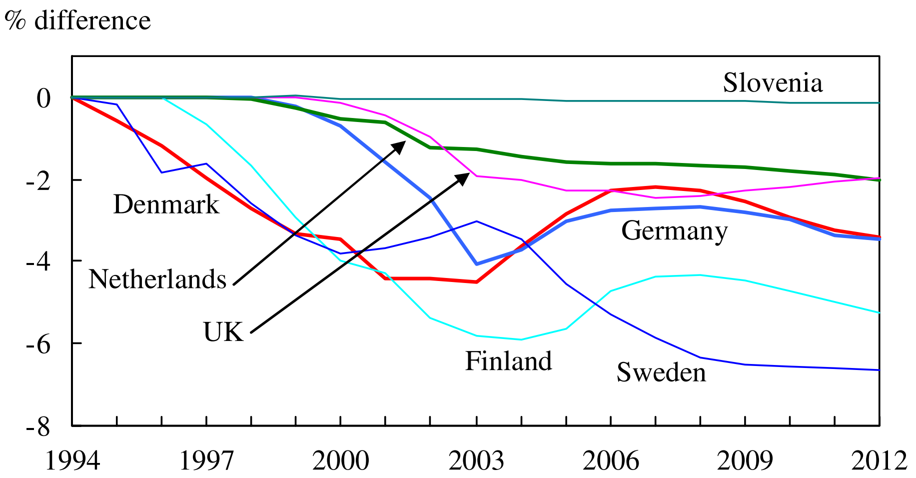
The scenario results show that there are reductions in GHGs in all six ETR regions from the ETR (see Chart 7.4). This is consistent with national policies to meet the European Burden Sharing Agreement targets, by which EU countries have agreed to emit a specified level of GHGs over the period 2008-12. The effects closely follow the results for total fuel consumption, with the largest reductions occurring in regions with the highest tax rates.

The largest reductions in emissions occur in Finland and Sweden. It should be noted that in most cases the fall in emissions is relatively larger than the fall in fuel demand, indicating that the tax policies are efficient at reducing emissions.

GDP

As a general rule, the effects of the ETR will be positive on economic activity, depending on how the revenues from the environmental taxes are recycled (see section 3.5). This is because tax distortions in the labour market are reduced in the revenue recycling measures. Lowering labour taxes encourage employers to hire more staff (in

CHART 7.4: THE EFFECT OF ETR ON GHG EMISSIONS



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

the case of employers' contributions) and encourage more people to join the labour force (in the case of income taxes). Unlike some economic models, E3ME does not assume that economies operate optimally and shifts in the tax burden will therefore not necessarily have a negative effect on output. However, it is likely that there will be short-term transition costs, so the gains may not be immediate. All six of the ETR countries have an increase in GDP as a result of the ETR (see Chart 7.5).

In Sweden, the effects take slightly longer to come through, as the very large increase in household electricity taxes depresses real incomes in the short run.

Finland has a short-term boost to GDP from the effects of the taxes on fuel demand, because a reduction in the demand for imported fuel improves the country's trade balance.

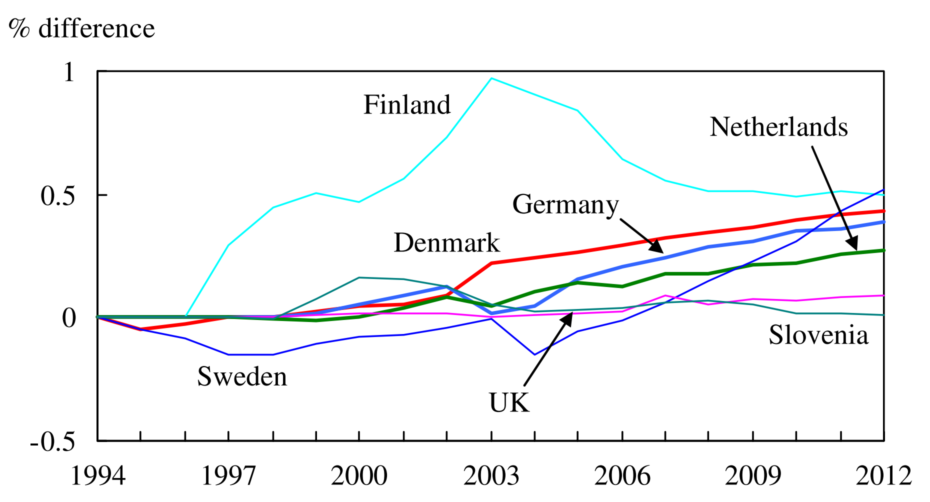
Employment effects

The ETR caused employment in some of the ETR countries to increase by as much as 0.5%. Employment increases because the revenue from the ETR is used to reduce employers social contributions, therefore wage costs are reduced, and hence firms are able to increase their labour force. This is the case for Denmark, Germany and the UK. In Denmark the ETR has an immediate effect on the level of employment, which remains nearly 0.5% higher throughout the modelling period (see Chart 7.6). In Germany a more modest increase in employment is recorded of approximately 0.2% increased employment against the reference case. However, in the UK the change in employment is small, this is because the revenue recycled to reduce social security contributions was much smaller.

Interestingly employment in Sweden was higher due to the ETR despite revenues being used to reduce income tax and not social security contributions. This is because the increase in GDP as a result of the ETR has caused employment to increase slightly compared to the reference case.

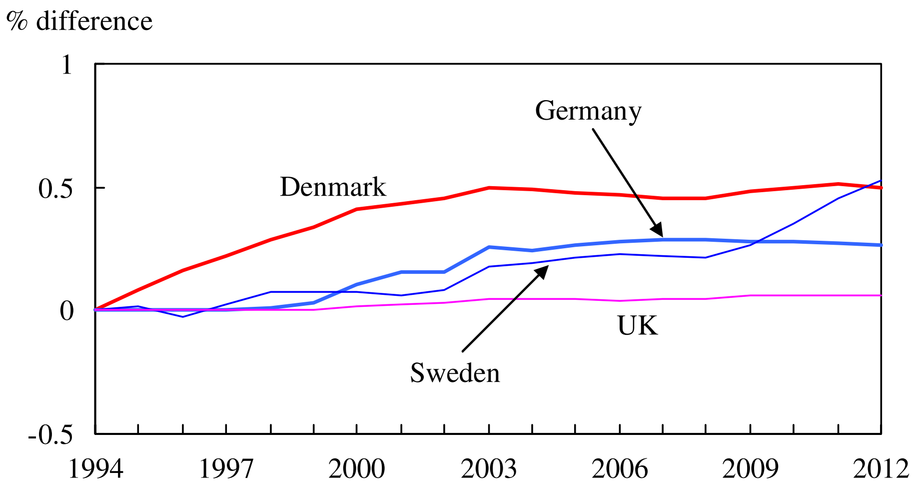
Investment levels remain unchanged for most of the ETR regions. Chart 7.7 shows that investment levels are virtually unchanged between the baseline and the reference

CHART 7.5: THE EFFECT OF ETR ON GDP



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

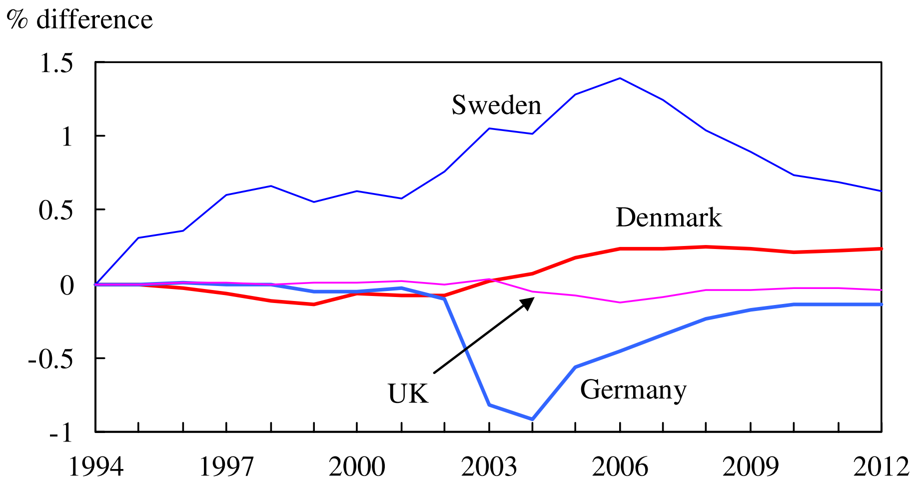
CHART 7.6: THE EFFECT OF ETR ON EMPLOYMENT



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

case for the UK and Denmark, (similarly for Finland, Slovenia and the Netherlands although this is not shown). In Sweden, investment increases as a result of the ETR by nearly 1.5% in 2006. Conversely, in Germany investment falls as a result of the ETR, this is due primarily to an increase in energy prices as a factor cost, but also due to the relative cost of capital to labour. The revenue recycled into social security contributions in Germany means that labour becomes relatively cheaper compared to capital and hence capital investment falls, albeit by less than 1% when compared to the reference case. Furthermore by 2012 the levels of investment are broadly similar between the baseline and the reference scenarios.

CHART 7.7: THE EFFECT OF ETR ON INVESTMENT



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

Inflationary effects

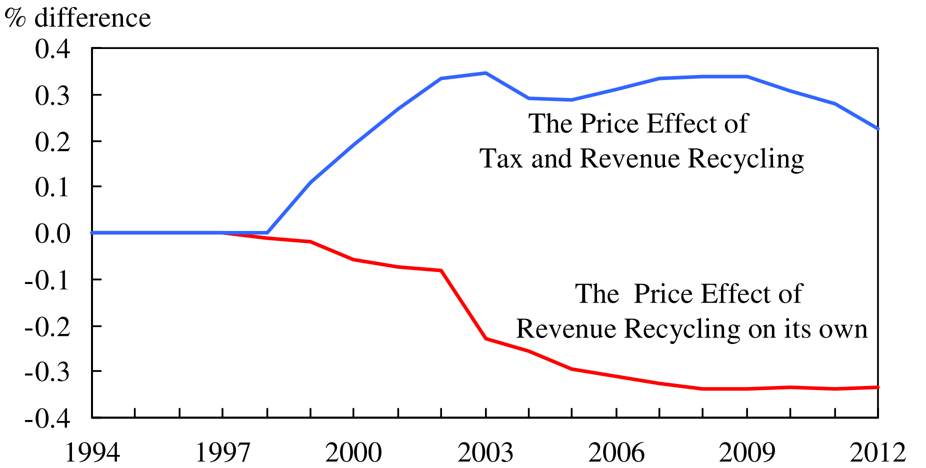
As the ETRs result in higher fuel prices it is considered likely that there will be an increase in the overall price level. The degree of this is likely to be dependent on the scale of the increase in fuel costs, how easy it is for industry and consumers to switch between fuels to cheaper alternatives (and non-energy inputs) and how much of the cost is passed on by industry to consumers (this is dependent on the level of competition in the industry, which is estimated econometrically for each region and sector). It should also be noted that the revenue recycling may have a depressing effect on inflation when the revenues are recycled through reductions in employers' social security contributions (ie labour costs). This is demonstrated for Germany (where just under half the revenues were used for reducing employers' contributions) in Chart 7.8.

In Denmark and the UK, there were no significant increases in the overall price index. In the UK this is because the tax is relatively small and was compensated with slightly cheaper labour costs. In Denmark the tax was larger, but was again compensated with lower labour costs (see Chart 7.9). There was little effect in Slovenia.

The measure of inflation shown in Chart 7.9, the consumer price index, will record a larger increase in cases where the taxes are levied on households rather than industry. The reason for this is that the consumer price index is a weighted average of the price of consumer products, including energy. In the cases where the tax is levied on households the whole tax is reflected in the consumer price index, rather than just the share that is passed on by industry. Therefore it is not unexpected that the largest increases are in the Netherlands and, in particular, in Sweden.

Wage effects are key to determining price increases, and the relative economic effects of price increases. The wage equations in E3ME are based on a union bargaining system with spillovers between sectors and regions, and reactions to productivity growth, average consumer prices and relative benefit and unemployment rates. A full set of parameters is estimated independently for each region and sector. For a more

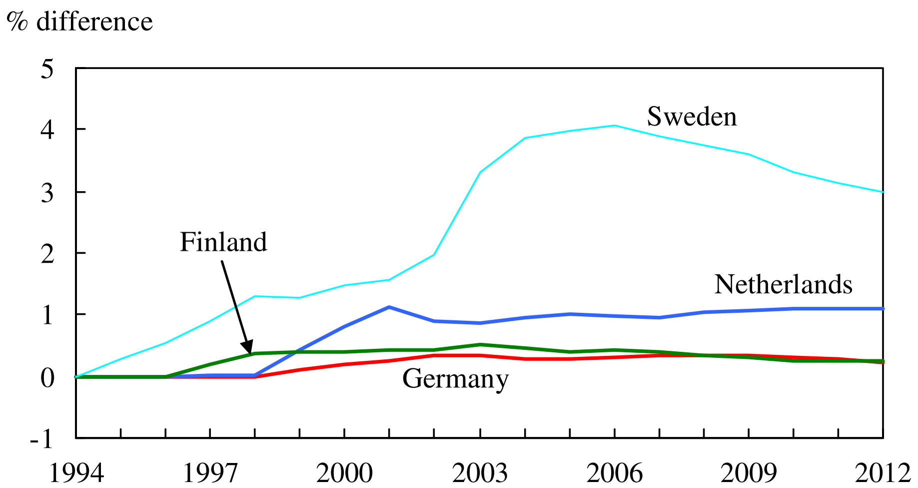
CHART 7.8: PRICE EFFECTS IN GERMANY



Note(s) : % difference is the difference between base case and the counterfactual reference case for Tax and Revenue Recycling and is the difference between the no revenue recycling case and the base case for revenue recycling.

Source(s) : CE.

CHART 7.9: CONSUMER PRICE INDEX



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

detailed analysis of E3ME's wage equations the reader should refer to chapter 8 of the online manual[7].

The largest increase in wages by far is in Sweden, where there is an average increase of 3-4% (roughly the same as the increase in the CPI). In the other regions, the effect on wages is in the region 0-0.5%, with the largest increases in the Netherlands and Finland.

In terms of competitiveness this is very important, because wages are the biggest single determinant of unit costs. The effect on industry prices in Sweden is not that great, however, with only an increase of around 0.3%. In the Netherlands and Finland, the average effect on prices is around 0.1%, and less in the other regions. Results for price effects by sector are discussed in section 7.11.

The Porter hypothesis

The Porter hypothesis suggests that environmental regulation can induce efficiency and innovation and improve competitiveness as efficiency gains partially, or more than fully, offset the costs of complying with the regulation. In the COMETR context, and in Work Package 4, environmental regulation has been more narrowly defined, however, as energy taxation implemented to encourage households and industries to behave in an environmentally-sustainable manner. On this definition, our results show, in contrast, that in the absence of revenue recycling mechanisms, ETR leads to a net loss of output in all examined countries (except Finland). However, when there is revenue recycling, ETR, as modelled within E3ME, produces a small 'double dividend' effect in every country, with GDP increasing by up to 0.5% compared to the Reference case.

In the following section we shall consider the individual impacts of the fuel taxes, the revenue recycling and the tax exemptions on each of the ETR countries.

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[7] http://www.camecon-e3memanual.com/

7.3 The Effects of ETR in Denmark

Most of the effects from the Danish ETR are seen in the 1990s

The Danish ETR raised the effective tax rates of coal and oil by 5-10%, and petrol and electricity by 10-15%. There was little change in the price of natural gas.

According to the tax revenue data, the taxes were highest in relative terms in the 1990s, and were not increased in line with the higher energy prices (electricity taxes for industry are the exception to this), or the introduction of the ETS in 2005. Therefore the largest relative effects from the ETR are near the start of the period, as shown in Chart 7.10.

It is not surprising therefore that the reduction in energy demand is greatest in the 1990s; after this point, the effects of the tax are diluted by higher energy prices (see Chart 7.11). This would appear to illustrate the fact that the Danish government could have achieved a larger decrease in emissions if it had kept environmental tax as a share of energy prices constant in the period when energy prices rose.

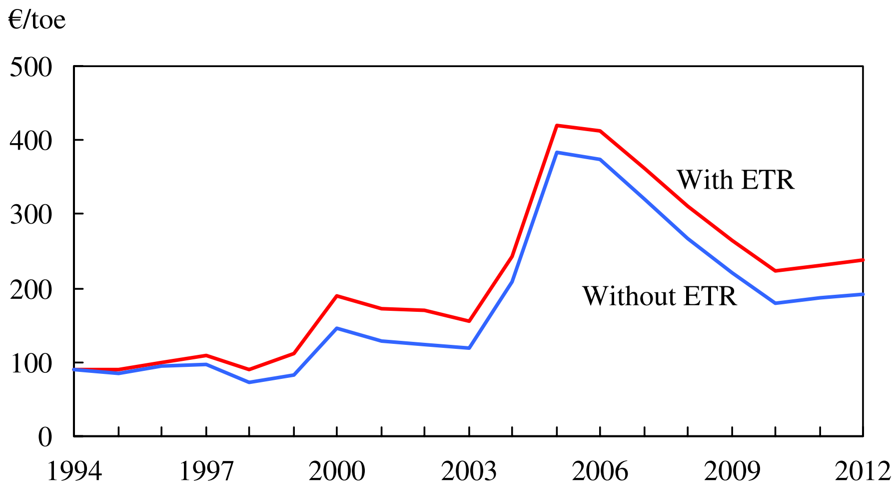
It should also be noted that where possible, Danish industry switches to using natural gas as an input rather than coal or electricity, but as power generation dominates demand for gas in Denmark, a fall in electricity consumption leads to a fall in the demand for gas.

In conducting this analysis, one should not ignore the effects of the taxes on motor spirit. The ETR leads to a 5% fall in the demand for middle-distillates, and this is an important factor explaining the difference between the fall in demand for fuel, and the fall in emissions.

Economic effects

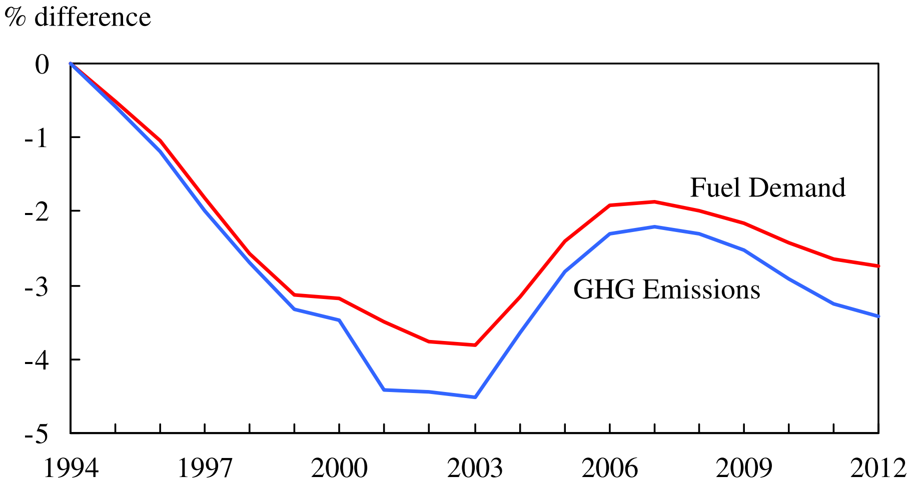
Apart from a small increase in investment, all of the government revenues from ETR are recycled through reductions in employers' social security contributions. This proved to be a very effective way of increasing economic activity with immediate increases in employment leading to higher average incomes, household consumption and GDP growth (Chart 7.12 shows the GDP and employment effects). The largest

CHART 7.10: COAL PRICES IN DENMARK



Source(s) : CE.

CHART 7.11: THE EFFECTS OF ETR: FUEL DEMAND AND GHG EMISSIONS IN DENMARK



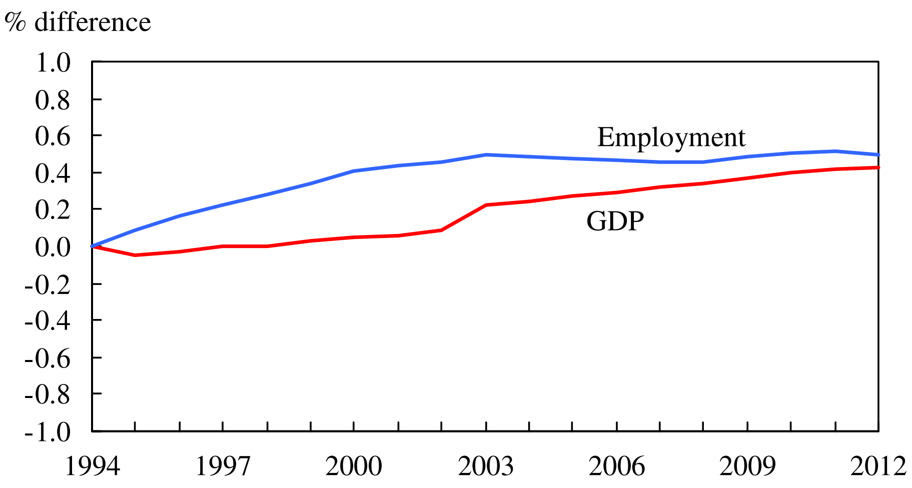
Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

increases in employment came in the retail and construction sectors (these two sectors account for around half of the overall growth in employment).

The ETR had very little impact on international trade into and out of Denmark, with virtually no change in exports and a small increase in imports in line with overall GDP growth.

There are no clear inflationary effects resulting from the Danish ETR, with prices falling in several sectors as a result of lower unit labour costs. This is a key factor in

CHART 7.12: THE EFFECTS OF ETR: GDP AND EMPLOYMENT IN DENMARK



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

explaining why there is not a relative decline in aggregate exports from Denmark between the baseline and reference cases.

7.4 The Effects of ETR in Germany

The German ETR

The German ETR started in 1999. It focused mainly on business use of energy, but included a component for household electricity use. Coal was not included in the German tax reforms.

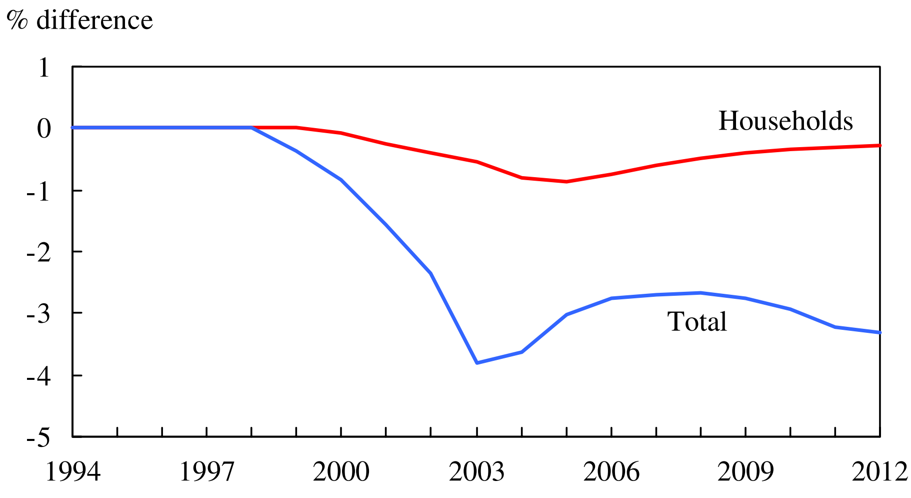
Taking this into account it is not surprising that there is a wide variation in energy price rises across the sectors, depending on the fuel inputs to each one. For example, in power generation, where coal is a major input, average energy prices only rose by 4%, but in food drink and tobacco, the increase was more than 15%. The increase in average road transport costs, and average energy prices for households, was less than 5%.

Overall the ETR reduces energy demand by around 3% (see Chart 7.13). After 2003 the decrease is less, due to the higher energy prices making the fuel taxes relatively smaller, but this increases again as energy prices decline in real terms over 2006-10. This partly reflects the assumption that energy taxes increase in line with consumer price inflation, not energy costs, over the forecast period.

Unsurprisingly, given that the taxes focus on industry rather than households, the initial reduction in energy demand from households is far smaller and diminishes over time. The only household tax included in the ETR was on electricity.

The predicted fall in GHG emissions in Germany is very closely linked to the fall in total fuel consumption. The main reason that emissions do not fall by more than fuel demand is that the German ETR does not include a tax on coal, so there is in fact a small increase in demand for coal in Germany as some industries switch to cheaper

CHART 7.13: THE EFFECTS OF ETR: FUEL DEMAND IN GERMANY



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

fuel options. It should be noted that were it not for the inclusion of the emissions trading scheme, the increase in demand for coal would probably have been higher.

Economic effects

The ETR in Germany produced a modest increase in GDP, around 0.2% in 2006, increasing to 0.4% over the forecast period to 2012. There is one notable slowdown in 2003-04 when the tax revenues from gas use increased substantially, as the power generation sector accounts for most gas consumption. The rise in gas use led to a strong increase in electricity prices. This had a negative short-term impact on investment (although it did slightly boost employment). However, once energy prices started to rise and the ETS was introduced in 2005, the effects of the ETR become much smaller in relative terms and growth in investment and GDP became faster.

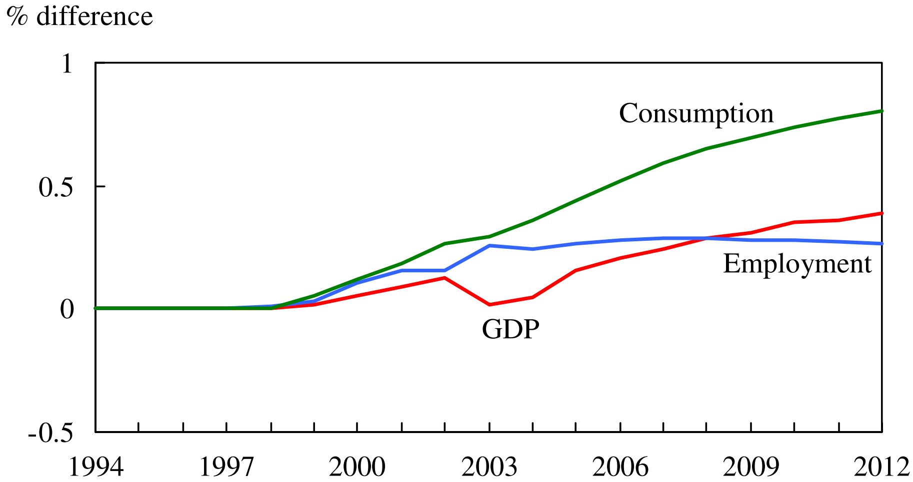
The combination of reductions in employers' and employees' social security contributions provides a direct boost to income, but also lowers labour costs and so increases employment and therefore average incomes. Chart 7.14 shows that it is in fact consumption that drives GDP growth, more than compensating for a slight worsening in trade performance (although part of the increase in imports will be a result of higher domestic household consumption).

Comparison with national study

Using a typical Baseline and Reference case scenario comparison, a report by DIW estimates changes on the economy between Reference and Baseline case. The Reference case is a counter-factual case where no ETRs were implemented; the Baseline case represents the outturn.

The DIW[8] report points to GDP in Germany rising by between 0.3% and 0.4% as a result of the ETR over the period 1999-2005, but this difference reduces to 0.1% in 2010 when compared with the Reference case. In contrast, our projections suggest no change to GDP in the short run and GDP begins to increase, relative to the Reference case in 2005 and continues rising to 2012 (see Chart 7.14).

CHART 7.14: THE EFFECTS OF ETR: GDP, CONSUMPTION AND EMPLOYMENT IN GERMANY



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

[8] Kohlhaas, M. 2005 Gesamtwirtschaftliche Effekte der ökologischen Steuerreform, DIW Berlin.

However, the differences between these results and the DIW study in assessing the effects of ETR are relatively small. The main difference in GDP growth between the DIW report and this study is due to the assumptions on the Reference case. The projection of the Reference case is calculated by removing the tax reform from the data/assumptions and then running a scenario based upon those changes and solving year-on-year in the typical manner, for an integrated European solution. Conversely, the DIW Reference case is based upon a number of assumptions used to condition the German economy. In this case DIW assumed that the counterfactual GDP will grow by 1.8%pa in the Reference case and that CO2 emissions would have grown by 0.9%pa. Given this, it is likely that the reference case projection in this report suggested a somewhat higher growth rate for Germany and hence provides a reason for the percentage difference between the Reference and the Baseline cases.

Furthermore the DIW study uses an endogenous government sector, where employment increased as a result of lower labour costs, due to the ETR.

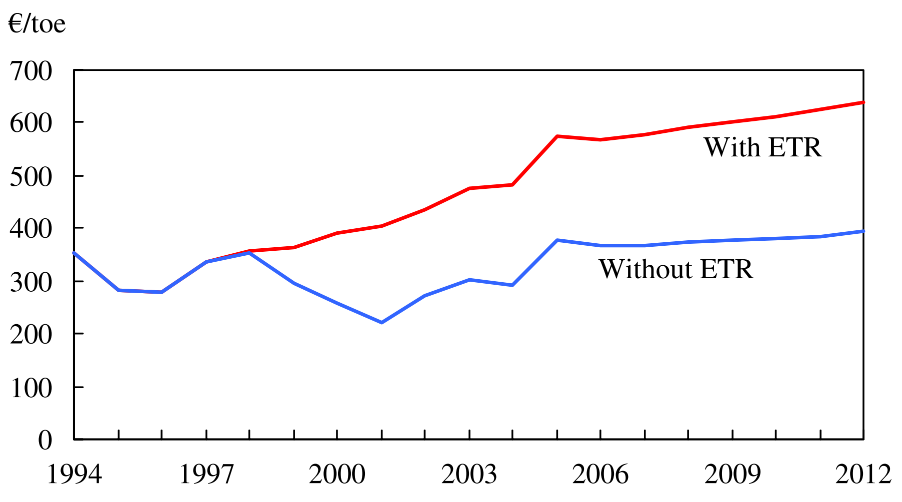
7.5 The Effects of ETR in the Netherlands

The Dutch ETR

There are certain similarities between the Dutch and Swedish tax reforms in that the bulk of the new revenues come from households' use of electricity. Although households and industry pay the same tax rates in the Netherlands, industry benefits from lower rates for high-volume users (households were assumed to fall into the lowest-volume category). The Dutch ETR was introduced in 1998, but the main effects come through from 1999. Aside from the increases in electricity prices, there was also an increase in taxes on gas (again with lower rates available for high-volume users) but very little change in taxes on coal, heavy oil and motor spirit.

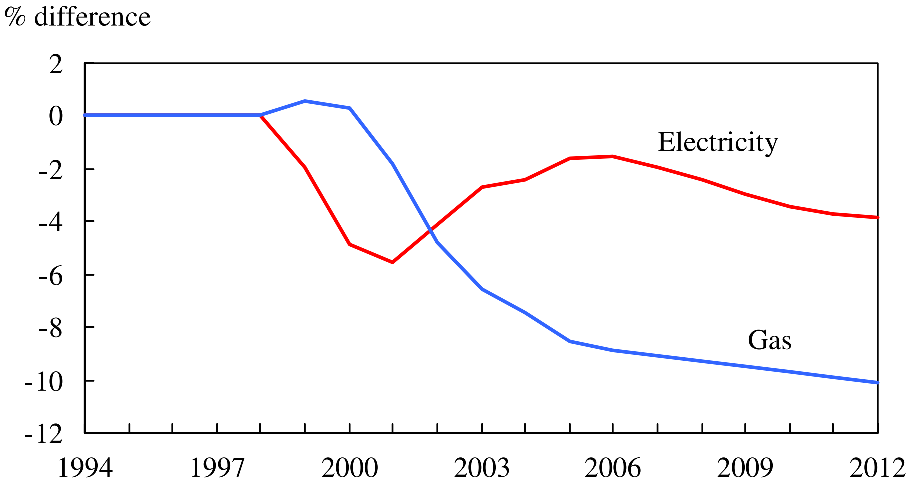
The effect on the electricity price was greatest in 2001, when the tax reforms almost doubled prices to households. However, revenues fell over 2001-04 and energy prices increased, as Chart 7.15 shows, and so the effective tax rates as a share of the total price fell, lessening the final impact.

CHART 7.15: THE EFFECTS OF ETR: AVERAGE HOUSEHOLD ENERGY PRICES IN THE NETHERLANDS



Source(s) : CE.

CHART 7.16: THE EFFECTS OF ETR: HOUSEHOLD ENERGY DEMAND IN THE NETHERLANDS



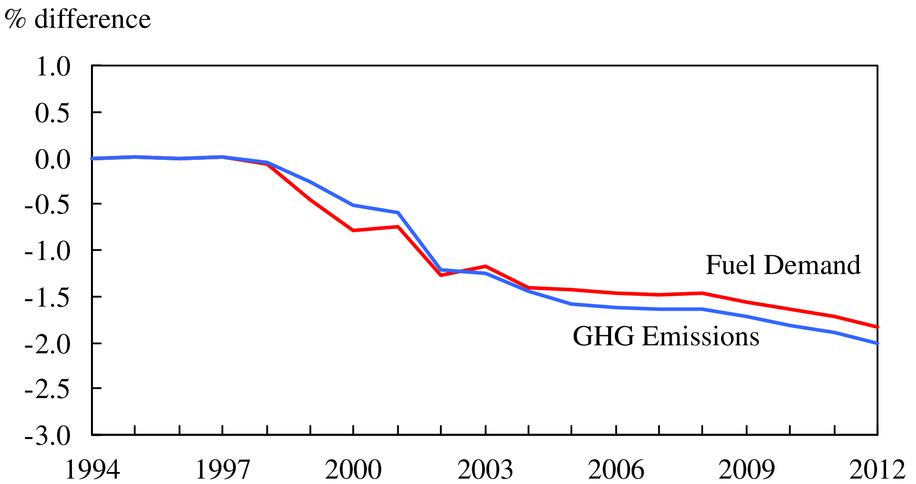
Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

Energy demand Although the price increases for gas were smaller, consumer demand for gas fell much more sharply than for electricity as a result of the tax reforms (see Chart 7.16). Electricity demand actually rebounds somewhat relative to the Reference case over 2001-05 when the electricity taxes are falling as a share of the total cost of electricity.

As gas accounts for a much larger share of household energy demand than electricity in the Netherlands, total household demand for fuel falls by more than 8% by 2012.

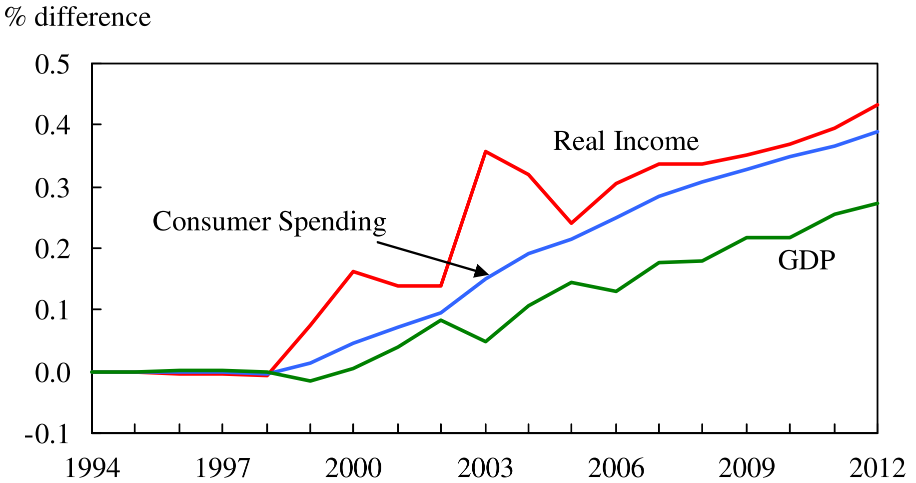
In other industries (particularly ones that use coal and oil) the demand for energy is largely unchanged and increases slightly in some cases. However, this is compensated

CHART 7.17: THE EFFECTS OF ETR: FUEL DEMAND AND GHG EMISSIONS IN THE NETHERLANDS



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

CHART 7.18: THE EFFECTS OF ETR: CONSUMER DEMAND IN THE NETHERLANDS



Note(s) : % difference is the difference between the base case and the counterfactual reference case.

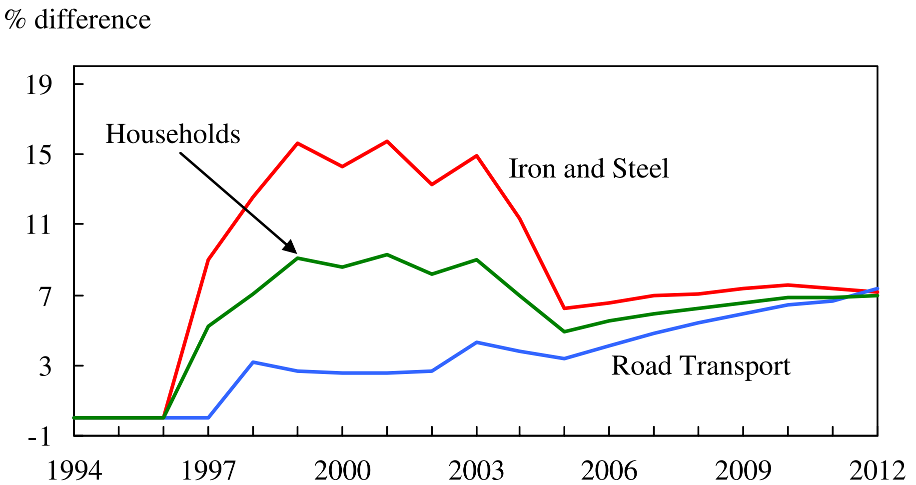
Source(s) : CE.

for by a fall in energy inputs to power generation, reacting to the lower demand for electricity. As 30-40% of Dutch electricity comes from coal, this reduces overall coal demand in the Netherlands, despite there not being a direct tax on coal. Because of the combined fall in demand for gas and coal, the difference in overall emissions is fairly similar to the change in aggregate fuel demand (see Chart 7.17).

Economic effects

The tax revenues from the Dutch reforms were recycled through reductions in income taxes. This boosts overall incomes and household consumption, as Chart 7.18 shows. In contrast there is almost no change in employment.

CHART 7.19: THE EFFECTS OF ETR: AVERAGE FUEL PRICES IN FINLAND



Note(s) : % difference is the difference between the base case and the counterfactual reference case.

Source(s) : CE.

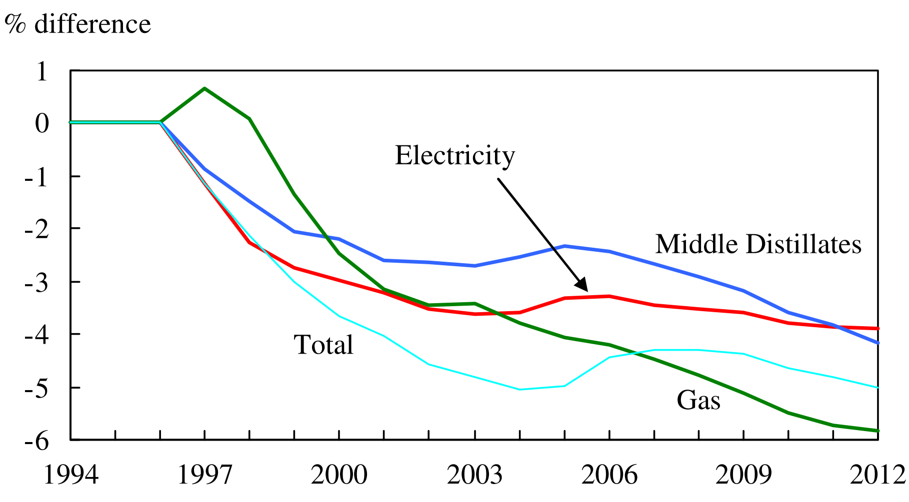
GDP does not increase as much as consumer spending because the slightly higher industrial prices have some adverse effect on trade.

7.6 The Effects of ETR in Finland

Environmental tax reform took place in Finland in 1997. Taxes were increased on all fuels for both business and households. The initial changes increased fuel prices by 10-15% for industry (depending on the fuel mix), and around 9% for households (see Chart 7.19). In the following years however, higher energy prices diluted the tax effects, particularly in industry dependent on oil and gas. Taxes on road fuels increased in two steps, in 1998 and in 2003, causing an overall increase of around 4% in the cost of motor spirit in 2004. As energy prices fall over 2006-12, the relative price effects of the ETR increase slightly, to around 6%.

The Finnish ETR, as Chart 7.20 shows, reduced fuel demand by around 5% in 2004, and the same amount in 2012. There are falls in demand for all of the main fuels (gas, electricity and middle distillates) of around 4% in 2004. The demand for coal and heavy oil is reduced even more, but from a lower base. Overall, greenhouse gas emissions fall by about 1 pp more than total fuel use, due to larger reductions in demand for the less common (but more polluting) fuels: coal and heavy oil.

CHART 7.20: THE EFFECTS OF ETR: FUEL DEMAND IN FINLAND



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

Economic effects

The effects of the higher fuel prices will be to reduce real household incomes in Finland and reduce the demand for exports from Finland. The revenue recycling in Finland is not explicit but is modelled through reductions in direct income taxes on the grounds that the alternative would have been higher income taxes. This should increase disposable incomes and household consumption, feeding through to the rest of the economy.

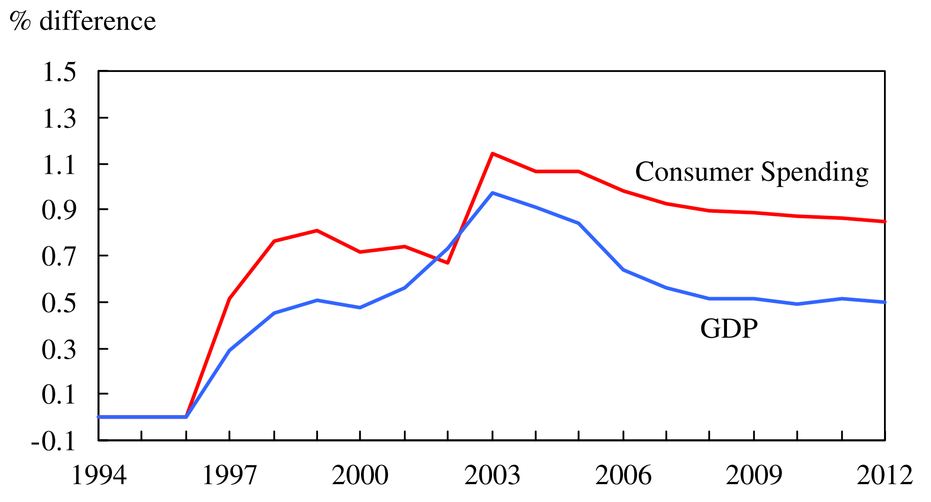
However, it turns out that the export effects are not significant, and over the period exports decrease by less than 0.05% and, in many sectors, exports increase (the reason is that the fuel taxes and revenue recycling will increase investment, which in turn will increase non-price competitiveness).

Finland is the only one of the examined regions to show an increase in GDP even without any revenue recycling. The main reason behind this is that the taxes fall almost exclusively on imports of energy products and so when energy demand falls there is an improvement in the international trade balance.

Consumer spending and GDP move very closely together over the historical period, with GDP growth also including reductions in energy imports (see Chart 7.21). Although the difference in GDP growth becomes less in the longer term, there is still a difference of around 0.5% in 2012.

In E3ME this is modelled through changing input-output (IO) coefficients. When energy demand falls, the IO coefficients for energy products are reduced. In regions that import most of their energy this means that imports of energy products fall. In Finland, this is the case for coal, and to a lesser extent oil. The sector that has the greatest demand for coal and for oil is power generation, accounting for 90% of coal demand and 25% of demand for heavy fuel oil. However, electricity is also generated in Finland from biofuels, nuclear power and renewables. One of the effects of the ETR is to promote these alternative forms of energy, and reduce imports of coal and

CHART 7.21: THE EFFECTS OF ETR: CONSUMER SPENDING AND GDP IN FINLAND



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

oil. As electricity prices are assumed to be government regulated, this is assumed to be achieved without a significant loss in real incomes, although company profitability will undoubtedly be affected.

7.7 The Effects of ETR in Sweden

The Swedish ETR

The data for tax revenues provided by Statistics Sweden are very detailed and provide a disaggregation that can be incorporated directly into E3ME.

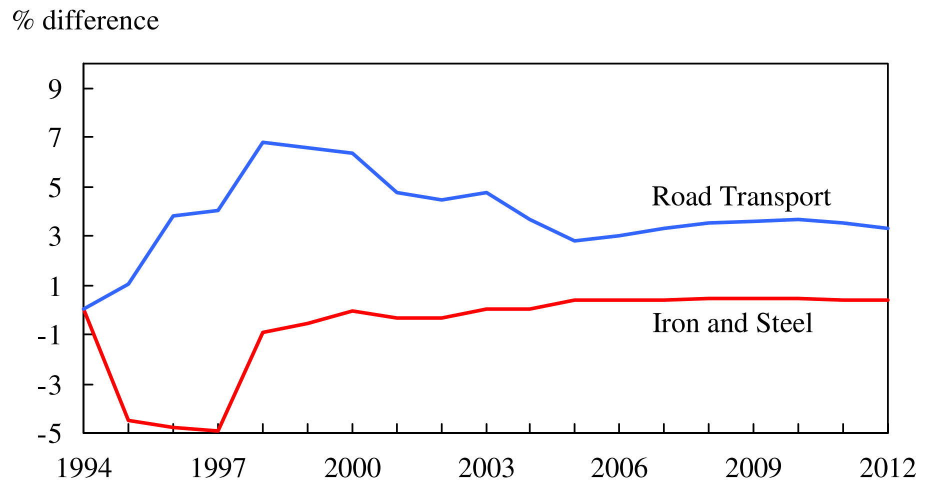
The Swedish package of reforms effectively moved much of the tax burden from industry to households, as industry energy taxes are set to 0 from 1993 for all the main fuels except motor spirits. This is illustrated in Chart 7.22, which shows the effects of ETR on average fuel prices in iron and steel industry, and road transport. In comparison, prices for households (mainly electricity) increased by more than 100% in 2003.

Chart 7.23 separates the fuel demand from households from the demand from other sectors, demonstrating the scale of the reduction in demand for fuel (mainly electricity) from households. In comparison, Chart 7.24 shows that there was little change in demand from most industries. Energy demand from power generation fell as a result of lower household demand for electricity. This illustrates how the ETR was a very effective way of reducing domestic energy demand. A tax increasing in real terms over 1994-2004 achieves a reduction in energy demand of 15-20% by 2010. When considering changes of this scale it should be noted that the estimated price elasticities may not be as accurate as for incremental changes and, as overall household energy demand falls the price elasticity is likely to become smaller, meaning that the actual fall in demand may be less. The net effect on the rest of the fuel user groups is close to zero.

Economic effects

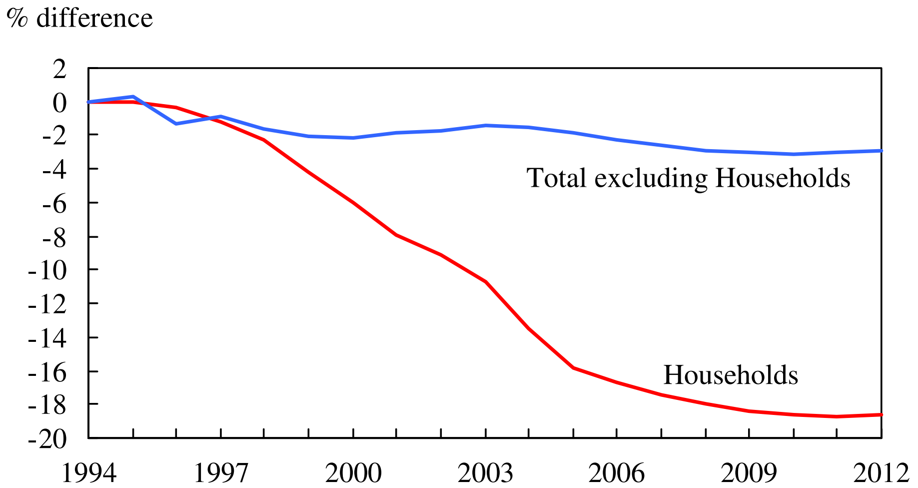
The effects of the increased fuel prices for households and the reductions in direct taxes should largely cancel each other out in Sweden as households are both paying

CHART 7.22: THE EFFECTS OF ETR: AVERAGE FUEL PRICES IN SWEDEN



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

CHART 7.23: THE EFFECTS OF ETR: FUEL DEMAND IN SWEDEN

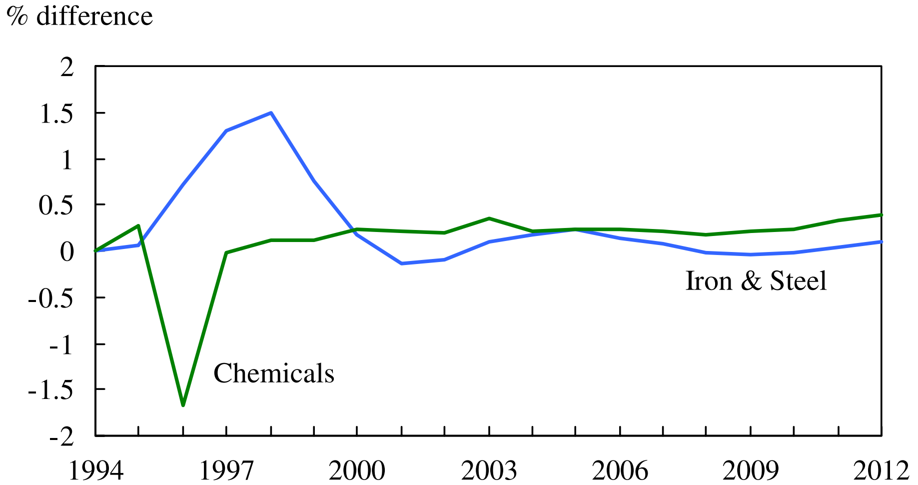


Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

the tax and receiving the benefits. However, the inflationary effects of the increased energy prices prove to be a deterrent to short-run consumption so that, although employment rises very slightly, there is not an increase in consumer spending.

One area of the economy that receives an immediate boost is industrial investment. Although this is generally regarded as the most volatile component of GDP, the results show a clear trend that investment increases as a result of the higher energy prices. This represents firms' investment in new energy-efficient equipment; and there is an increase in both manufacturing and service sectors.

CHART 7.24: THE EFFECTS OF ETR: INDUSTRIAL FUEL DEMAND IN SWEDEN



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

Beyond 2006 the tax effects start to fall in relative terms (compared to the Reference case), as energy prices rise and the ETS forces costs higher for the energy-intensive sectors. The inflationary effects of the ETR are therefore also reduced in relative terms. This, combined with the effects of higher investment over 1994-2005, brings about an increase in consumer spending, which in turn increases GDP and employment. Conversely, investment falls after 2006, suggesting that the boost to consumption will not last much beyond 2010 and in the long run there may be an increase in GDP of something in the range of 0.5% (see Chart 7.25).

7.8 The Effects of ETR in the UK

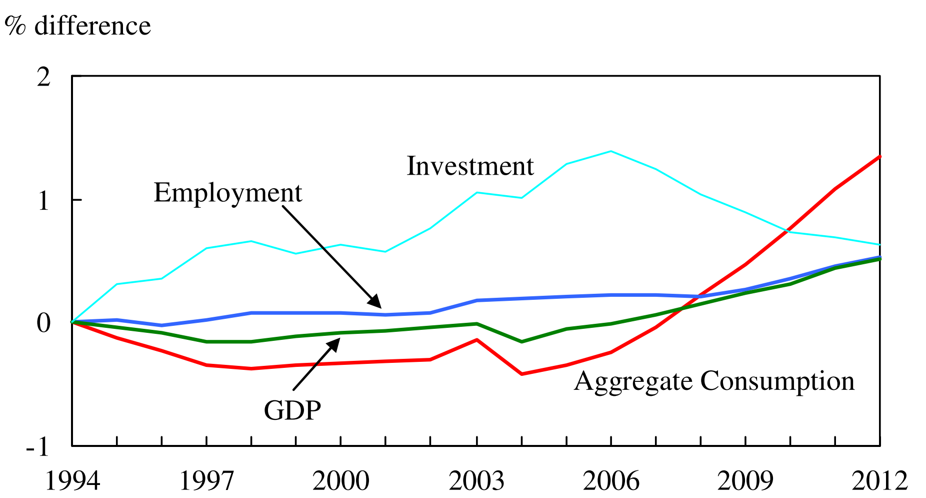
The UK ETR

The climate change levy in the UK came into effect in 2001 but was announced in 1999 to give companies time to adjust their practices. The aim of the charge was to increase the rate of tax paid by business for fuels used for energy, according to their energy content, to encourage the more efficient use of energy and help the UK meet its GHG targets. Households did not directly pay any of this tax. The climate change levy is much smaller than some of the other tax reforms examined, raising only €1,200m in 2004. However, in the time between the announcement of the tax and its implementation, the tax gained a lot of media coverage and this raised awareness about the environment in general, particularly in the business sector.

The main reason that the announcement effect had such a large impact on commerce was that it was not able to enter into any negotiated agreements, unlike the industrial sectors, and therefore faced a higher tax rate. It should be noted that in these scenarios only the price effects (plus the announcement effect in commerce) are being modelled, and any reductions in fuel demand resulting from the negotiated agreements are not included in the difference between the base and reference cases, mainly due to measurement issues. As such, these results will likely underestimate the full impact of the ETR.

E3ME is not able to model such awareness variables, and to add this feature was outside the remit of COMETR. However, extensive research has been done on the

CHART 7.25: THE EFFECTS OF ETR: MACROECONOMIC EFFECTS IN SWEDEN



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

issue with Cambridge Econometrics' UK energy-environment-economy model, MDM-E3, for the UK government (see references), including a separation of the price and non-price effects. This research found (through the use of a dummy variable) that there was a substantial reduction in energy use in the retail and commerce sector ('Other Final Users' in E3ME) from the non-price effect, mainly because this sector could not negotiate any reductions in CCL payments. As MDM-E3 and E3ME are very similar in design and structure it was decided to impose the non-price effects on to the E3ME results exogenously, so that the results presented showed the accumulation of research on the topic.

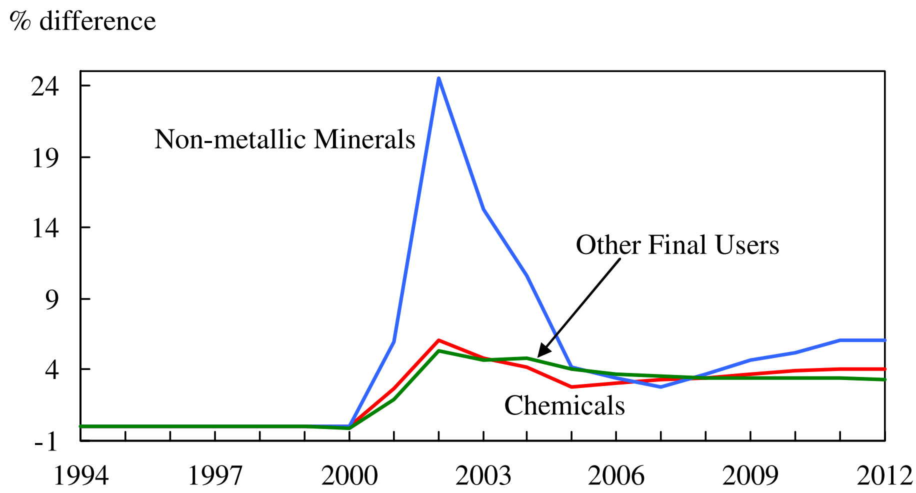
The study showed that 'most of the effects of the CCL are attributed to the 'pure' announcement effect, not to the price effect. The effect of the CCL on the energy-intensive sectors is far less because most firms in these sectors do not pay the full rate of the Levy, and because no announcement effects are detected in these sectors'.

The price increase for each fuel-user group is dependent on whether that group is subject to the charge, and the fuel mix used by that group. In most cases the increases in energy costs were, as Chart 7.26 shows, small (5% or less). Only sectors with a heavy reliance on coal (such as non-metallic mineral products) saw larger increases, and even these differences decreased when world energy prices themselves rose in 2004-05.

Sectors that are more reliant on natural gas, such as food and drink, also faced a slightly higher increase in costs (the data indicate that government revenues from gas and electricity use were roughly equal, despite electricity consumption being around 50% higher). There is no increase in energy costs for households, power generation or the transport sectors.

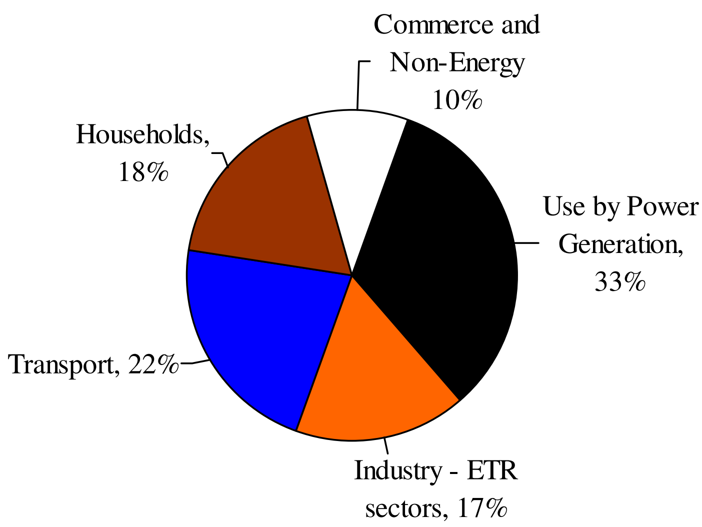
As the price increases in the UK are small and affect sectors that account, as Chart 7.27 shows, for only 17% of total energy use, we would not expect to see a

CHART 7.26: THE EFFECTS OF ETR: FUEL PRICES IN SELECTED UK SECTORS



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

CHART 7.27: SHARE OF FUEL USE IN THE UK, 2000



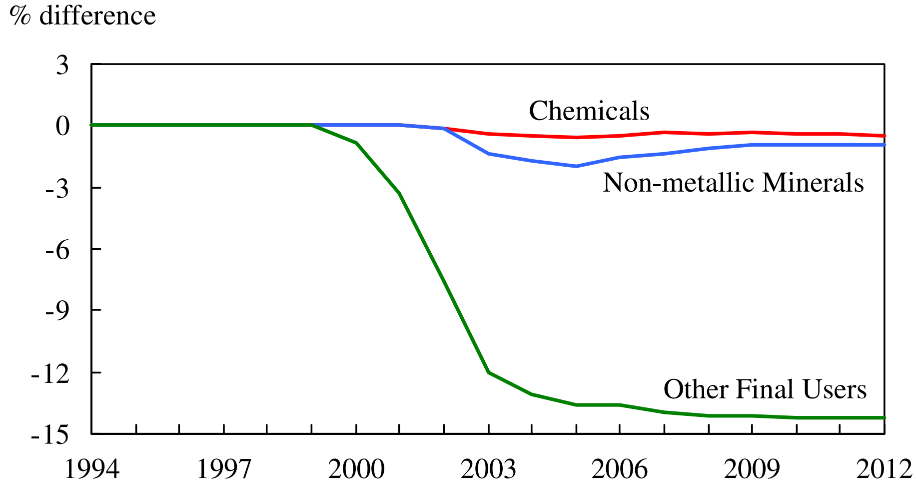
Source(s) : CE.

particularly large fall in overall energy use and emissions from the price effects alone.

In addition to this, fuel demand in the UK tends to be fairly inelastic to price increases. In most of the sectors covered by the climate change levy, the fall in fuel demand is in the region of 1-2% or less. This is very small when compared to the non-price effects forecast for the commerce sector. This sector ('Other final use' in E3ME) has, as Chart 7.28 shows, a reduction in fuel demand of 14% by 2012.

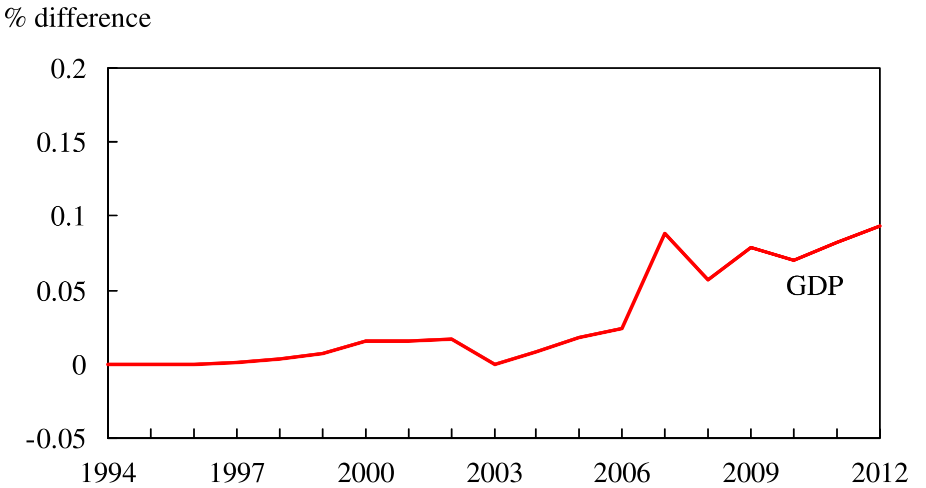
Economic effects Although the UK CCL was able to achieve quite a large reduction in energy demand, this was mostly through non-economic factors including the announcement effect. In

CHART 7.28: THE EFFECTS OF ETR: FUEL DEMAND IN THE UK



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

CHART 7.29: THE EFFECTS OF ETR: CHANGES IN UK GDP



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

actual fact the tax levied on British industry was very small and much smaller than the other ETRs in the 1990s. Consequently we would not expect to see very much change in economic activity. The revenue recycling occurs through reductions in employers' social security contributions, which have the effect of keeping down inflationary factors, but also of raising employment. This leads to a small, but noticeable effect on GDP over the forecast period, although it should be noted that, changes in employment and incomes take several years to produce effects on GDP (see Chart 7.29).

7.9 The Effects of ETR in Slovenia

Fuel Demand

The CO2 tax in Slovenia was only applied to consumption of natural gas over the period 1994-2004, with a higher rate for households. Power generation was exempt from the tax and was therefore not included in the analysis.

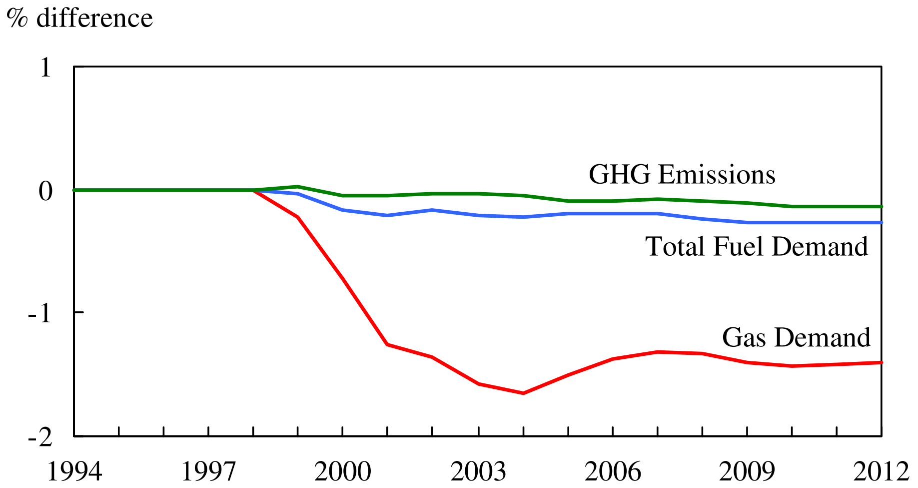
Overall demand for gas fell by around 1.5% in 2004. As in many of the other regions, the tax rates were not increased in line with higher energy costs. There was very little change in the demand for other fuels, with only a small increase in electricity demand as households switch from gas. Therefore, the overall impact on fuel demand was much less than the effect on the demand for gas, only around 0.3% (see Chart 7.30).

Not surprisingly as the tax is on natural gas, one of the cleanest fuels, the reduction in greenhouse-gas emissions is much lower than the overall reduction in fuel demand.

Economic effects

The revenue recycling in Slovenia was assumed to be in the form of reductions in income tax. This gives an immediate boost to real household incomes and consumption. However, there is virtually no resulting increase in employment. In the longer term, imports increase as a result of higher domestic prices in some of the energy intensive sectors, notably basic metals (which is important to Slovenia). As trade plays a very important role in the Slovenian economy this reduces the overall effects on GDP.

CHART 7.30: THE EFFECTS OF ETR: FUEL DEMAND AND GHG EMISSIONS IN SLOVENIA

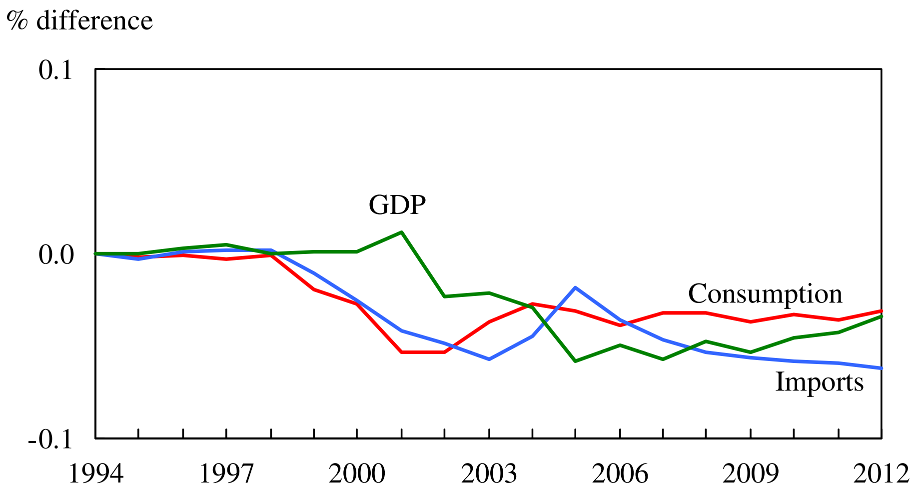


Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

The immediate effect of the reforms is a small (around 0.15%) increase in GDP. In the long term there is no increase in GDP attributable to the tax reforms.

As the Slovenian tax was not a true ETR, and had no attached revenue recycling mechanism, it is perhaps more appropriate to consider the case with only the tax, and noting that there is an overall increase in the tax burden. The results for energy demand are largely unchanged from Chart 7.30 above (as the energy prices are roughly the same with or without revenue recycling). GDP, however, falls by around 0.05% (see Chart 7.31) as a result of the environmental tax with no revenue recycling.

CHART 7.31: THE EFFECTS OF ETR: ECONOMIC EFFECTS IN SLOVENIA



Note(s) : % difference is the difference between the no revenue recycling case and the counterfactual reference case.
Source(s) : CE.

This is mainly due to a fall in export volumes of nearly 0.1%.

7.10 The Effects of ETR in the Non-ETR Countries

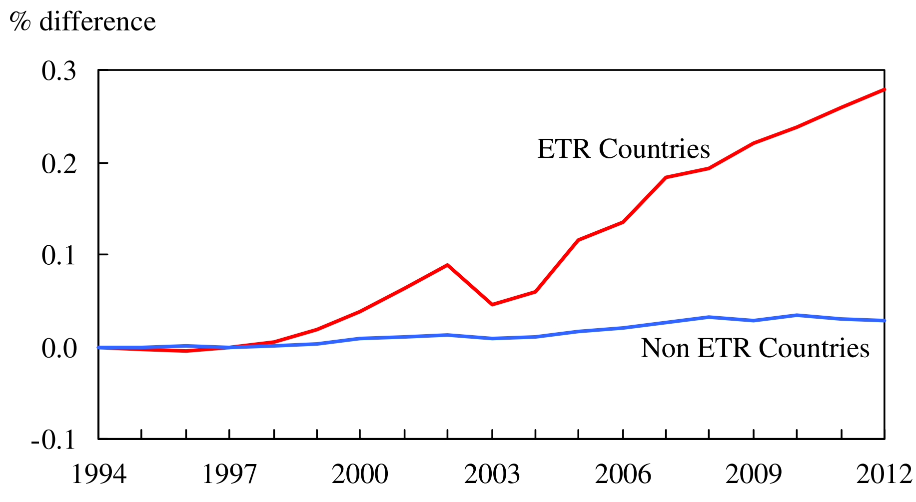
The aggregate GDP effects of the 1990s tax reforms are dominated by the results for Germany. Considering the German tax reforms on their own, there is an impact on all other regions, with and without their own tax reforms. It is not therefore surprising that there is little overall effect in Europe before the implementation of the German tax reforms in 1999 (see Chart 7.32).

The effects in the other European countries are thus dominated by their trade patterns with Germany. Regions that export to Germany themselves gain when German demand for their product grows. It should be noted that results for other ETR regions trading with Germany will include similar effects.

The overall scale of the difference is very small, an increase in GDP of 0.3% in the ETR countries equates to about half of one quarter's growth, while an increase of 0.05% is six times smaller again.

Table 7.1 shows the effects of the ETR in the six countries and whether there are any cross regional effects between the ETR countries and non-ETR countries. The results show that the ETRs have very little effect on the greenhouse gas emissions of other EU countries. This is consistent with there being little carbon leakage within the EU, the process by which a reduction in carbon emissions in one region leads to an increase in carbon emissions in a second region, due to an ETR causing a relocation of industry. It also highlights that unilateral ETR action has a positive effect on greenhouse gas emissions without having a detrimental effect elsewhere: this is a key finding and is discussed further in the COMETR DL5.2 report.

CHART 7.32: THE EFFECTS OF ETR: GDP IN ETR AND NON ETR COUNTRIES



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

TABLE 7.1: THE EFFECTS OF ETR: GHG IN EU 25

	2000	2004	2008	2012
Belgium	-0.01	-0.05	-0.08	-0.13
Denmark	-3.46	-3.63	-2.30	-3.43
Germany	-0.69	-3.73	-2.68	-3.45
Greece	0.00	0.00	0.00	0.00
Spain	0.00	0.01	0.08	0.03
France	0.00	-0.05	-0.11	0.19
Ireland	0.00	0.00	0.00	0.00
Italy	0.00	0.00	0.00	-0.01
Luxembourg	0.00	0.00	0.00	0.00
Netherlands	-0.52	-1.46	-1.65	-2.01
Austria	0.00	0.02	0.05	0.05
Portugal	0.01	0.00	0.01	0.01
Finland	-3.98	-5.90	-4.34	-5.23
Sweden	-3.80	-3.47	-6.35	-6.63
United Kingdom	-0.12	-2.02	-2.42	-1.97
Czech Republic	0.00	0.01	0.01	-0.02
Estonia	0.00	0.00	0.00	0.00
Cyprus	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00
Hungary	0.00	0.00	0.00	0.00
Malta	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00
Slovenia	-0.05	-0.05	-0.10	-0.13
Slovakia	0.00	0.00	0.00	0.00
Total	-0.34	-1.47	-1.15	-1.29

Note(s) : difference is the % difference between the base case and the counterfactual reference case.

GDP changes are shown in Table 7.2, interestingly only Belgium experiences a reduction in GDP, by 2012, as a result of the ETRs, albeit a very small reduction. Most of the non-ETR countries experience no change in GDP, furthermore, the increases in GDP experienced by the ETR countries is small although not insignificant.

TABLE 7.2: THE EFFECTS OF ETR: GDP IN EU 25

	2000	2004	2008	2012
Belgium	0.02	0.02	-0.05	-0.08
Denmark	0.05	0.24	0.34	0.43
Germany	0.05	0.05	0.29	0.39
Greece	0.00	0.00	0.00	0.00
Spain	0.01	0.02	0.03	0.05
France	0.01	0.01	0.05	0.03
Ireland	0.00	0.00	0.00	0.00
Italy	0.00	0.02	0.06	0.06
Luxembourg	0.00	0.00	0.00	0.00
Netherlands	0.00	0.11	0.18	0.27
Austria	0.02	0.03	0.07	0.06
Portugal	0.00	-0.02	-0.01	0.02
Finland	0.47	0.91	0.51	0.50
Sweden	-0.08	-0.15	0.14	0.52
United Kingdom	0.02	0.01	0.06	0.09
Czech Republic	0.01	-0.01	0.00	0.00
Estonia	0.00	0.00	0.00	0.00
Cyprus*	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00
Hungary	0.01	0.01	0.01	0.01
Malta*	0.00	0.00	0.00	0.00
Poland	0.01	0.02	0.02	0.03
Slovenia	0.16	0.03	0.07	0.01
Slovakia	0.02	0.01	0.02	0.00
Total	0.02	0.04	0.12	0.16

Note(s) : difference is the % difference between the base case and the counterfactual reference case.

7.11 The Effects of ETR on Competitiveness in Individual Sectors

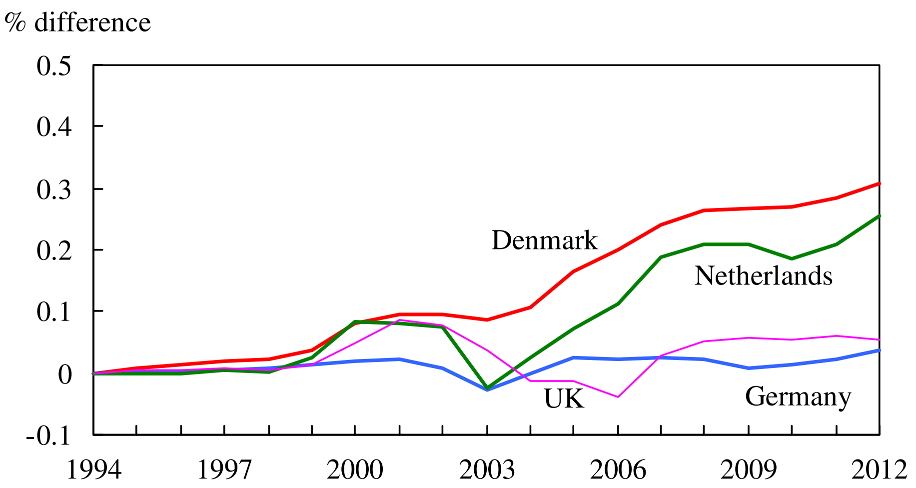
A direct method for investigating the impact on competitiveness is to determine whether or not the introduction of ETR caused export and import levels to change in the ETR regions. Chart 7.33 shows the effects of the ETR on aggregate exports by region.

In the largest two ETR regions, Germany and the UK the ETR has very little effect on exports, similarly there was little effect on exports in Finland and Sweden[9]. However Denmark and the Netherlands see a small increase in exports over the period, in the case of Denmark this is the result of lower labour costs as revenues are recycled by reducing the social security contribution.

Sweden witnesses, as Chart 7.34 shows, the largest increase in imports, aggregate imports are 0.8% higher as a result of the ETR. It is unlikely that this represents a reduction in competitiveness in the domestic market for home producers, rather, given that GDP increases by 0.5% in Sweden and that revenue is recycled into reducing income taxes, it is more probable that imports increase as a result of increased consumer spending. Both Germany and the UK, the two largest ETR economies, see little change in imports as a result of the ETR.

The COMETR project focuses on four of the most energy-intensive E3ME sectors, plus food and pharmaceuticals to provide a comparison. These are defined in Table 7.3 below at the NACE 2-digit level.

CHART 7.33: THE EFFECT OF ETR ON EXPORTS



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

[9] Sweden and Finland were not shown on chart 7.32 for presentational reasons.

TABLE 7.3: DEFINITION OF COMETR SECTORS

E3ME Sector	NACE Definition
5 – Food, Drink and Tobacco	15, 16
7 – Wood and Paper	20, 21
10 – Pharmaceuticals	24.4
11 – Chemicals nes	24 (ex 24.4)
13 – Non-Metallic Mineral Products	26
14 – Basic Metals	27

Before analysing the individual sectors, it is worth looking at what proportion of inputs comes from the energy sectors. This has been covered more extensively in Work Package 3, Table 7.4 shows the proportions used in the E3ME model. The values are formed by using the coefficients from the base year (2000) input-output tables and are a share of gross output (so wage costs and profit are included in the denominator).

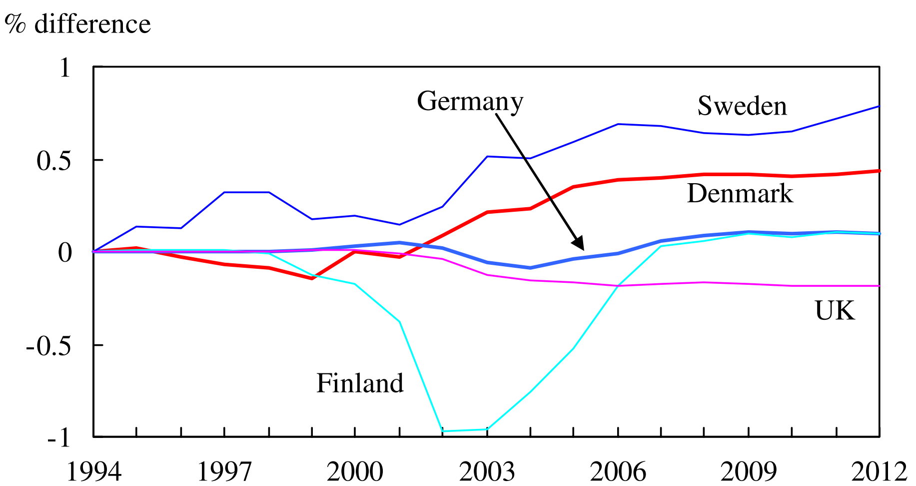
These are the sectors, which it is expected, will face the largest increases in energy costs, and therefore face the biggest threat from the ETRs.

We would not expect to see much impact on these sectors in the regions where a large proportion of the tax increases fall on households (ie The Netherlands and Sweden). It should also be noted that firms in these industries will benefit from lower wage costs in regions where there is revenue recycling through employers' social security contributions. Finally, the effects of higher overall growth rates in each country (and the rest of Europe) will give a further boost to product demand.

Input-output analysis

E3ME's input output tables for the ETR regions are sourced from Eurostat, except for the UK (ONS) and Slovenia (GTAP database). In each case they are converted to E3ME's 42 industrial sectors (for chemicals and pharmaceuticals this usually requires

CHART 7.34: THE EFFECT OF ETR ON IMPORTS



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

TABLE 7.4: ENERGY AS A SHARE OF TURNOVER (%)[10]

	DK	DE	NL	FI	SE	UK	SI
Food, Drink & Tobacco	1.5	2.0	1.5	1.4	1.0	1.5	1.9
Wood & Paper	1.9	3.3	2.9	5.1	3.7	3.0	6.5
Pharmaceuticals	0.4	7.2	0.0	6.5	0.3	0.9	0.0
Other Chems	4.2	6.5	17.5	8.9	8.4	3.9	4.3
Non-Metallic Minerals	5.4	5.8	4.2	3.5	4.4	4.4	8.9
Basic Metals	3.0	8.7	5.8	6.6	4.5	4.7	9.4

Source(s) : CE, E3ME database.

an estimate as separate data for these sectors are not normally available). The modelling exercise will not use these exact numbers because input-output coefficients are adjusted on an annual basis following a logistic growth path. However, Table 7.4 still gives a good indication of the importance of energy as an input to each sector and region, with the figures being expressed as a percentage of turnover.

As was found in Work Package 3, Table 7.4 shows that even in the most energy-intensive industries, energy does not represent a large share of inputs. Only in one case, Other Chemicals in the Netherlands, does the share of energy inputs in turnover exceed 10%. In most cases the figure is around 5%, with non-metallic minerals and basic metals apparently having slightly larger shares.

Price increases

If energy represents around 5% of an industry's input costs (turnover – profit), then even a 50% increase in energy costs is going to lead to only a 2.5% increase in total input costs – even assuming that the industry is unable to reduce its fuel consumption or substitute between different fuel inputs. This may or may not be absorbed by firms within the industry (if there were perfect competition within the industry it would be completely absorbed, if there were no competition it would be completely passed on). The effect of any price increases will depend on the relevant price elasticities (domestic and export) for the industry's products. Typically these would be less than one, so a 2.5% increase in prices would not lead to a 2.5% decrease in product demand. Consequently, even in the energy-intensive sectors we would not expect to see large falls in output.

Table 7.5 shows the results for 2004. This year was chosen because it is the final data-point in the input series; by 2004 the ETRs are in place, but there is no blurring

TABLE 7.5: CHANGE IN INDUSTRY PRICES, 2004

(% difference of baseline from reference case)

	DK	DE	NL	FI	SE	UK	SI
Food, Drink & Tobacco	0.01	0.05	0.00	0.46	1.69	0.00	0.04
Wood & Paper	-0.57	-0.40	-0.34	-0.26	-0.33	-0.48	-0.32
Pharmaceuticals	0.01	-0.09	-0.01	0.87	0.05	0.09	-0.02
Other Chems	0.32	0.72	0.11	0.36	0.28	0.36	0.08
Non-Metallic Minerals	0.33	0.46	0.26	0.77	1.06	0.29	0.16
Basic Metals	0.51	0.43	0.50	0.53	0.48	0.62	0.46

[10] Figures for the Pharmaceuticals and Other Chemicals sectors are estimates (except for the UK) as these sectors are not explicitly defined at the NACE 2-digit level. These estimates are derived by summing across the rows and columns of the input-output table and taking relative gross output shares. For Germany and Finland the allocation of fuel use to Pharmaceuticals seems unreasonably high and it is likely that most of this demand should in fact have been allocated to Other Chemicals.

of results by the assumption that tax rates remain constant in real terms after 2004.

As expected, the largest increases in prices are in the non-metallic mineral products and basic metals sectors. Prices fall in the wood and paper sector (which operates in an EU market rather than national markets). This is mainly due to a reduction in labour costs in the sector (which form a much larger share of input costs than energy does), and this reduction is mainly a result of reductions in social security payments in Germany and the UK.

Only two of the sectors show price rises above 1%. These are both in Sweden, where the effects are actually an indirect result of higher consumer prices, particularly in electricity (from the ETR) which in turns leads to an increase in wages. In most other cases (excluding wood and paper) the differences are in the range of 0.2-0.4%.

In most cases the price increases also include a factor for an increase in investment. This mainly represents firms' decisions to purchase new machinery in response to higher energy prices. While this may have a negative short-term effect in price competitiveness, it will improve long-term non-price competitiveness through the production of higher-quality output (which may again command higher prices).

Table 7.6 compares the effects of the ETR on export prices in an energy intensive industry, basic metals, and a non-energy intensive industry, pharmaceuticals. Although basic metals is an energy intensive industry, the effects on export prices are small for two reasons; firstly export prices for basic metals are to a large extent decided by the world commodity markets and secondly because a number of energy intensive industries are exempt from the ETR. However, in all the ETR countries, with the exception of Germany, the export prices were higher in 2004 for basic metals than for pharmaceuticals.

Changes in output

The effects of the ETRs on industry output are less easy to interpret because they include a number of different factors:

- price effects outlined above
- non-price effects from additional investment
- consumer demand
- activity in export markets
- production in competing import markets

TABLE 7.6: CHANGE IN EXPORT PRICES, 2004

(% difference of baseline from reference case)

	DK	DE	NL	FI	SE	UK	SI
Basic Metals	0.49	0.41	0.50	0.58	0.51	0.90	0.46
Pharmaceuticals	0.20	0.82	0.00	0.22	0.21	0.16	0.00

TABLE 7.7: INCREASE IN INDUSTRY GROSS OUTPUT, 2004

(% difference of baseline from reference case)

	DK	DE	NL	FI	SE	UK	SI
Food, Drink & Tobacco	0.65	0.56	0.13	0.64	4.24	0.02	0.28
Wood & Paper	0.29	0.17	-0.27	0.06	0.19	0.04	0.04
Pharmaceuticals	0.08	-0.02	-0.06	0.14	-0.05	0.00	-0.04
Other Chems	0.03	0.00	0.00	0.31	0.46	-0.07	-0.07
Non-Metallic Minerals	0.08	-0.28	0.05	0.54	0.31	-0.03	0.02
Basic Metals	0.08	-0.15	0.63	0.08	0.08	-0.16	0.00

Table 7.7 shows the percentage increase or decrease in gross output at factor cost (which excludes tax payments) for each of the examined industries, again in 2004. The results show that, in many, cases the over-riding effect is higher domestic demand from consumers.

In most cases, gross output in the affected industries increases slightly. This is not entirely unexpected given the modest nature of the price increases recorded. The scale of the increases varies across sectors much more than across countries. The smallest differences are in the UK where the ETR was smallest. This suggests that domestic demand is a key determinant in industry output.

Food & drink in Sweden is a special case in the results: prices do rise in Sweden in the food and drink industry (see Table 7.5). However, this is not by as much as the overall consumer price index, which rises primarily due to electricity costs.

Consequently, food & drink becomes comparatively cheaper and receives a larger share of consumer spending, in turn consumer spending is boosted overall by reductions in income tax. Consumer demand accounts for half of gross output in the food & drink industry.

Chart 7.35 shows that gross output in the basic metals sector remains largely unchanged in most of the ETR regions, however, in the Netherlands it increases by over 2%, this is due to substantial changes in investment in this industry, as shown in Chart 7.36, which in turn boosts its non-price competitiveness.

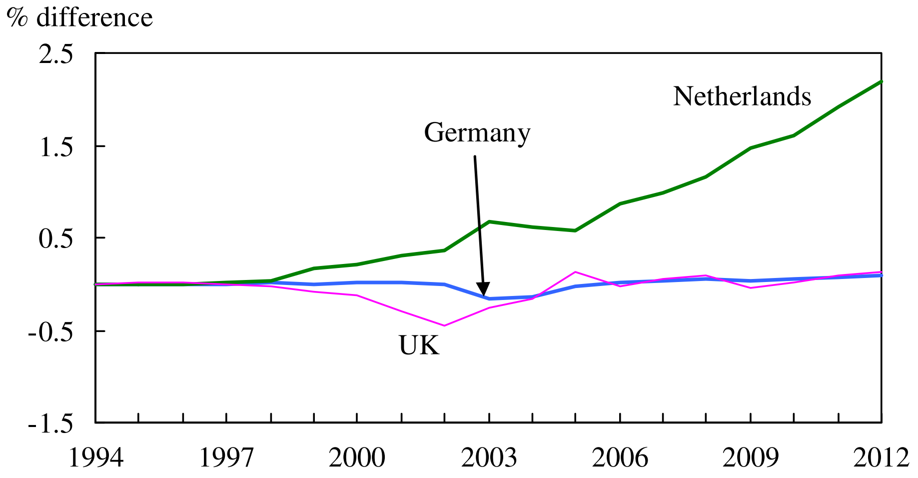
The effects of increasing investment are crucial in determining the long-term results in several of the examined sectors. Investment (along with R&D spending) determines product quality and non-price competitiveness, and increased investment can more than compensate for moderate price rises.

One of the effects of the ETR could be that industries invest in lower carbon technology in order to reduce their overall energy use. However, higher energy prices also represent an element of uncertainty in the economy and may persuade firms to defer or cancel investment plans. Chart 7.36 shows the change in investment in the basic metals sector as a result of the ETR for Germany, the UK and the Netherlands, it is clear to see that the increase in investment in basic metals in the Netherlands due to the ETR results in the increased gross output.

7.12 The Effects of the Exemptions

It is not always easy to define the exemptions on the environmental taxes. For example, there may be little difference between a lower tax rate and an exemption

CHART 7.35: THE EFFECT OF ETR ON BASIC METALS GROSS OUTPUT



Note(s) : % difference is the difference between the base case and the counterfactual reference case.
Source(s) : CE.

from a higher tax rate. It is almost impossible to obtain data for lost revenues from exemptions, and the data that do exist are likely to include other non-payments.

In the COMETR scenario for no exemptions we have defined a tax with no exemptions as the full tax rate, and revenues from this tax are calculated as tax rate * fuel use. This is the opposite case to the Baseline scenario, where tax rates are defined as revenues/fuel use. This approach makes the implicit assumption that all non-payments are exemptions and not, for example, due to tax evasion.

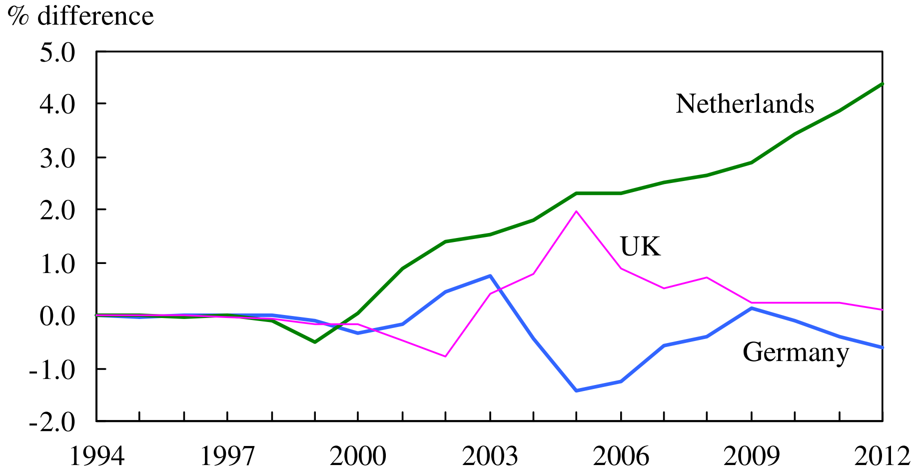
Generally, the effects are fairly linear, in that the higher tax rates cause a larger decrease in fuel use and emissions, and this feeds through to the wider economy. Usually the effects of the exemptions are quite small, however.

The largest effect is in the Netherlands, because the tiered electricity and gas rates to business are assumed to be exemptions, and therefore, when these are removed, industry pays the highest tax rates and the effects on fuel demand are much greater. In comparison, there is little difference in Sweden.

As we do not have separate data for tax rates and revenues for Slovenia it is not possible to separate the exemptions.

Charts 7.37 to 7.42 below show the difference the exemptions make to fuel use.

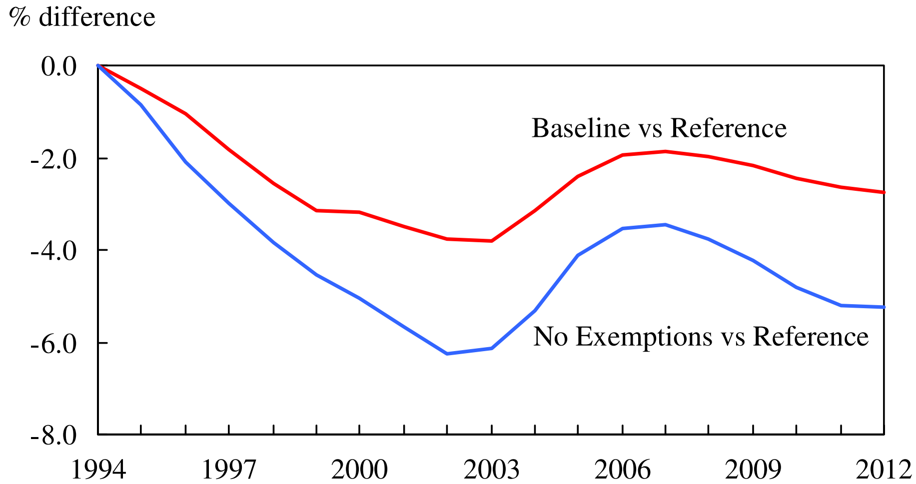
CHART 7.36: THE EFFECT OF ETR ON INVESTMENT IN BASIC METALS



Note(s) : % difference is the difference between the base case and the counterfactual reference case.

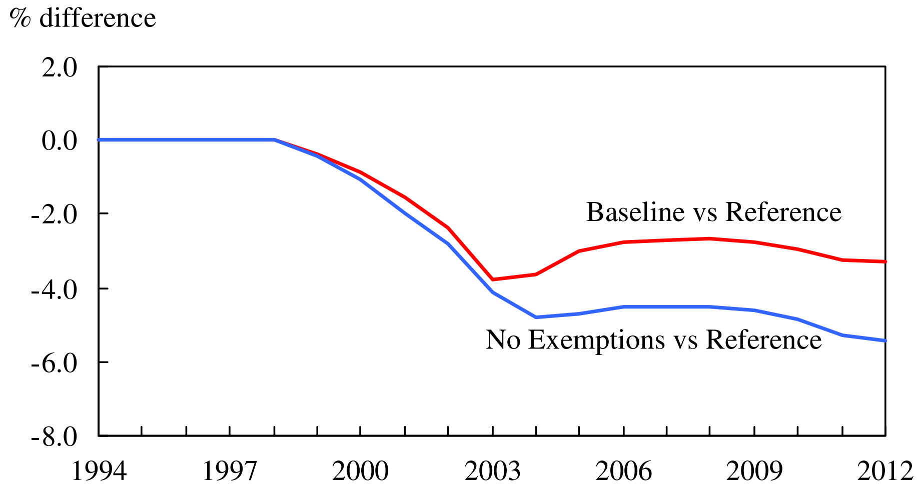
Source(s) : CE.

CHART 7.37: THE EFFECTS OF EXEMPTIONS: FUEL USE IN DENMARK



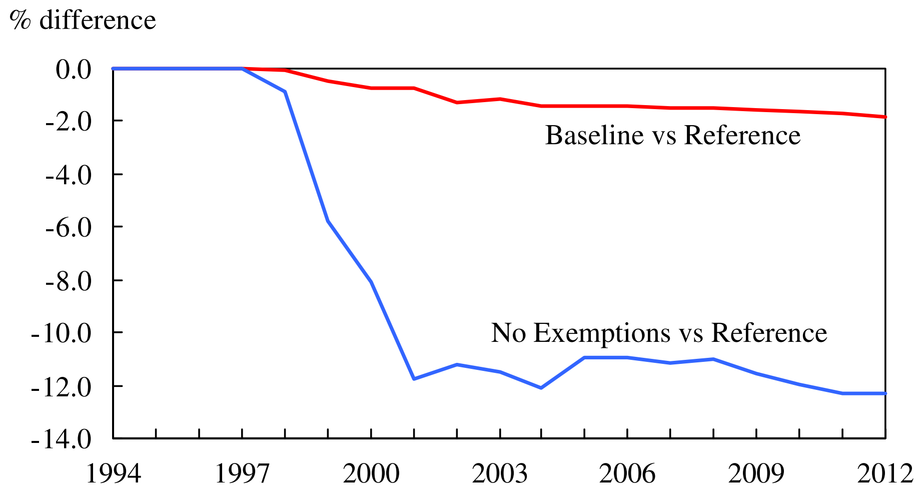
Source(s) : CE.

CHART 7.38: THE EFFECTS OF EXEMPTIONS: FUEL USE IN GERMANY



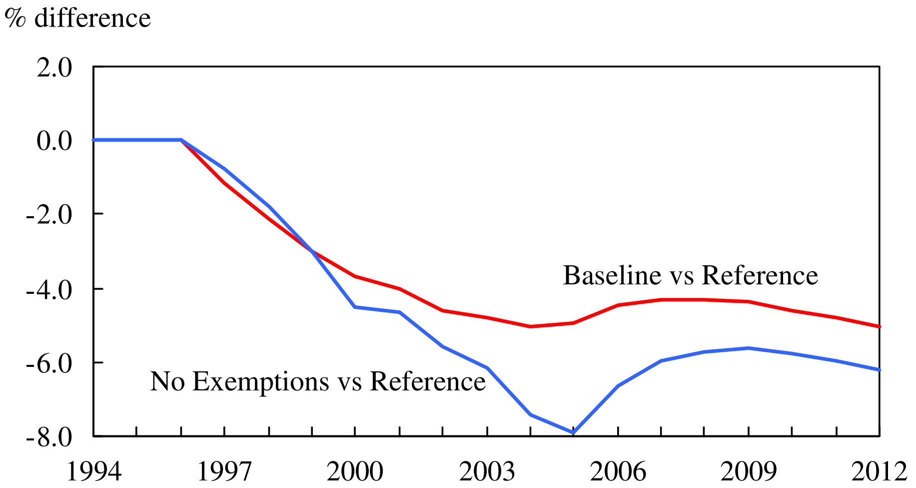
Source(s) : CE.

CHART 7.39: THE EFFECTS OF EXEMPTIONS: FUEL USE IN THE NETHERLANDS



Source(s) : CE.

CHART 7.40: THE EFFECTS OF EXEMPTIONS: FUEL USE IN FINLAND



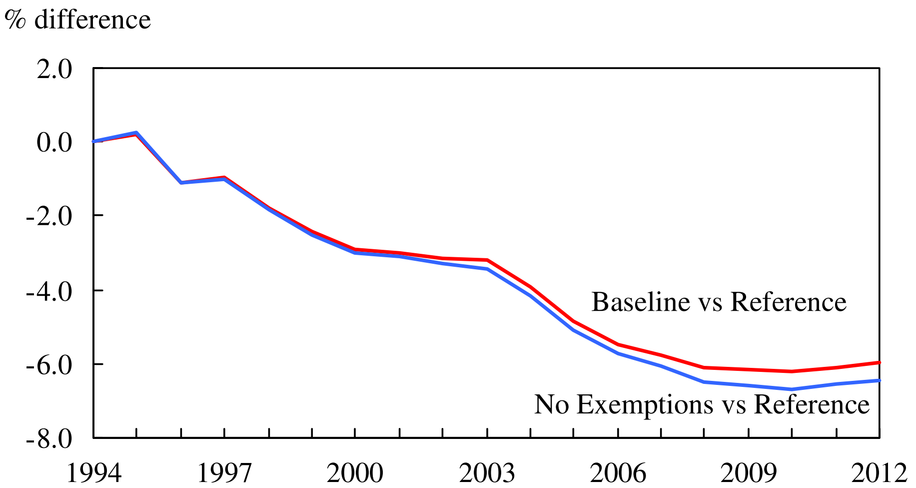
Source(s) : CE.

7.13 Isolating the Effects of the Taxes

This section looks briefly at one of the alternative scenarios that is designed to identify the effects of the energy taxes on their own without any revenue recycling. We would expect the higher energy prices on their own to have a negative impact on GDP, although in one region, Finland, GDP increases due to energy imports (particularly oil and gas) falling, as discussed in section 7.6.

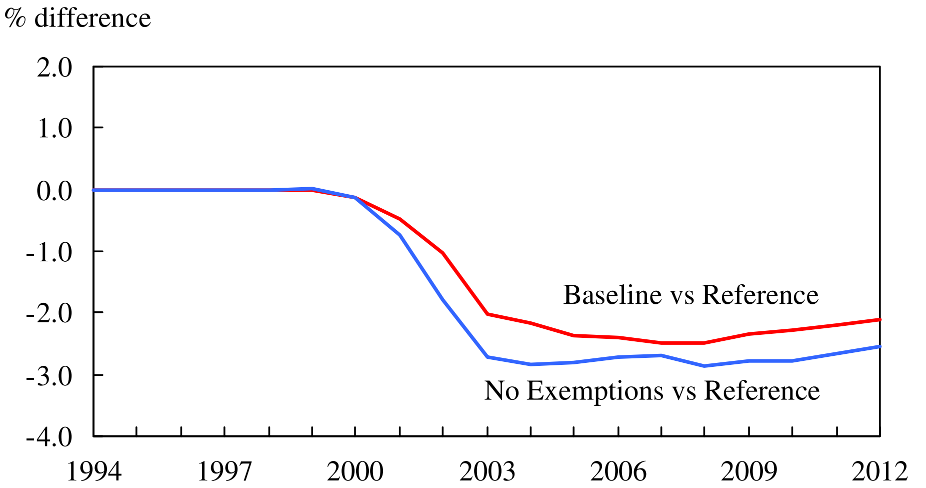
The assumptions underlying this analysis are stylised and therefore not necessarily realistic. As the national governments are not using the extra revenues to reduce labour taxes or increase spending, it is assumed that they are used simply to reduce

CHART 7.41: THE EFFECTS OF EXEMPTIONS: FUEL USE IN SWEDEN



Source(s) : CE.

CHART 7.42: THE EFFECTS OF EXEMPTIONS: FUEL USE IN THE UK

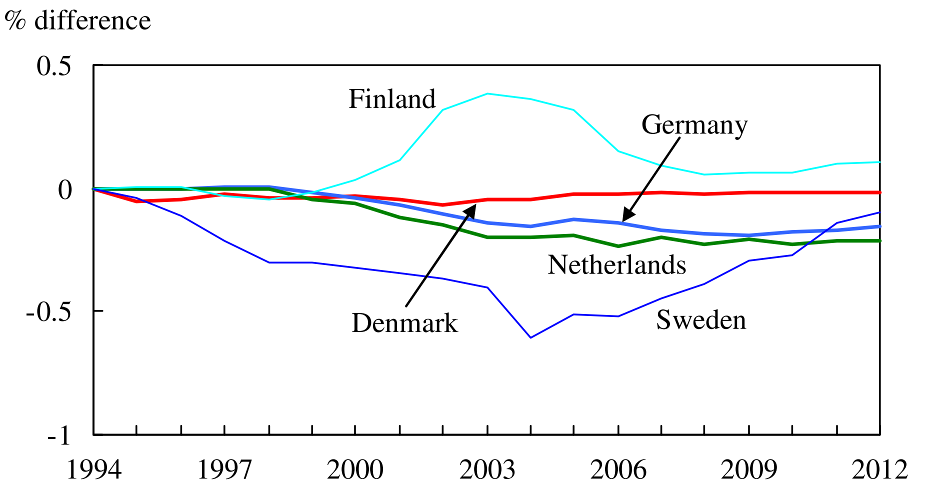


Source(s) : CE.

national debt. As the government sector and interest rates are exogenous in E3ME, this is effectively saying that there is an increase in the overall tax burden and the revenues raised by government are leaving the system. The overall effect (higher fuel prices with no compensating measures) is equivalent to an increase in world energy prices in countries that have no domestic oil and gas resources.

The level of the tax in the UK was too small to appear on Chart 7.43 below so has been removed (the effect on GDP was in the region of -0.02%). In Slovenia, the environmental tax was used as a revenue-raising instrument with no recycling mechanism; these results are discussed in section 7.9.

CHART 7.43: THE EFFECT OF ETR WITHOUT REVENUE RECYCLING ON GDP



Note(s) : % difference is the difference between the base case and the no revenue recycling case.
Source(s) : CE.

The results are broadly in line with expectations for most of the regions. The largest tax reforms were in Sweden, where the inflationary consequences had a significant effect on real household incomes and consumption. As household spending is the largest single contributor to GDP, it is not surprising that Chart 7.43 shows a relatively large fall in GDP in Sweden, particularly over the period of the introduction of ETR.

Household spending is also reduced in the Netherlands as a result of higher electricity prices.

Effects on employment varied across the countries examined. The key determinants of employment are the effects of changes in output and the various elasticities between employment and output and employment and energy prices. Any impact on wages from higher consumer prices will also affect employment rates, but it is assumed that employers' social security rates do not change (as there is no revenue recycling in this scenario).

There were small falls in employment in the region of 0.02% in Denmark and Germany but larger falls of up to 0.1% in the Netherlands and Finland. There was little change in Sweden and Slovenia, but a slight increase in the UK, as businesses substituted labour for energy.

7.14 Sensitivity of the Results to Key Inputs

Introduction

It is important to check the robustness of the modelling results to changes in key inputs. As the scenarios focus on changing patterns of energy use, one of the most important inputs is energy prices. Previous results in this chapter have already illustrated how the influence of environmental taxes became less as world energy prices increased over the period 2004-05; and it cannot be assumed that the effects will not diminish at other times and under other circumstances.

To test the sensitivity of the results to changes in energy prices, two additional sets of model runs (Baseline and Reference cases) were created, and the results were examined for major differences from the main set of results (see Tables 7.8 and 7.9).

These extra model runs were identical to the main project scenarios except that the energy prices fed into E3ME's energy submodel were reduced by 10% in one set (low) and increased by 10% in the other (high). This increase or decrease was applied to all energy products in all countries in each year over 1994-2012, with a 1 pp increase or decrease in each year from 1994 to 2004. The counterfactual runs were for the historical data available for 1994 to 2003. No explicit reason is given for the increase in energy prices and these extra model runs cannot be considered as well-defined scenarios, because other exogenous model inputs (eg world growth, ETS allowance prices) are unchanged.

TABLE 7.8: HIGH FUEL PRICES – TOTAL FUEL DEMAND

(% difference of baseline from reference case)

	1994	1998	2002	2006	2010
DK	0.00	-2.56	-3.76	-1.93	-2.44
DE	0.00	0.00	-2.36	-2.76	-3.02
NL	0.00	-0.07	-1.24	-1.46	-1.64
FI	0.00	-2.09	-4.53	-4.37	-4.54
SE	0.00	-1.78	-3.12	-5.40	-6.09
UK	0.00	0.00	-1.05	-2.40	-2.29
SI	0.00	0.00	-0.17	-0.19	-0.19

TABLE 7.9: LOW FUEL PRICES – TOTAL FUEL DEMAND

(% difference of baseline from reference case)

	1994	1998	2002	2006	2010
DK	0.00	-2.56	-3.78	-1.92	-2.43
DE	0.00	0.00	-2.36	-2.75	-2.91
NL	0.00	-0.07	-1.27	-1.46	-1.64
FI	0.00	-2.14	-4.65	-4.50	-4.70
SE	0.00	-1.78	-3.16	-5.60	-6.36
UK	0.00	0.00	-1.02	-2.35	-2.25
SI	0.00	0.00	-0.17	-0.19	-0.26

Results The results of this exercise show that, as expected, the impact of the energy taxes is higher in the low price scenario in the two countries with the largest effects, Finland and Sweden. This is because the taxes have a larger relative effect when energy prices excluding taxes are lower. The difference in the reduction in fuel demand ranges from zero to around 0.25pp in 2012 between the high and low price scenarios. The true result, reported previously in this chapter, sits halfway in between. This means that up to 2% of the reported difference could be attributable to a 10% change in the oil price in either direction.

There is virtually no difference in the largest countries, Germany and the UK. If anything, the taxes have a larger effect when there is a higher oil price. It is not obviously clear why this is, but it may well be a result of the relatively small scale of the taxes, and the fact that they were only introduced later in the period, when the oil prices were already lower/higher in these scenarios. In the Netherlands, the bulk of the tax fell on domestic electricity use, in which prices changed much less as a result of the change in oil price (ie not much of the change was passed on to consumers and less than in Sweden) so we would not expect to see much change in the results. It should also be noted that the UK and the Netherlands are oil-producing countries and so will react slightly differently to the other countries to a change in world oil prices.

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Leakage analysis within a decoupling framework

WP5

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1. Introduction

This paper assesses the evolution of specific economic sectors in several EU member states, in particular those EU member states which implemented environmental tax reforms (ETRs), using two different methodological approaches.

The first approach comprises decoupling analysis, which assesses the linkages between the development of environmental and economic variables over time, i.e. whether a change in an economic variable, for example GDP, is reflected in a comparable change in an environmental variable, such as energy consumption, or whether no recognisable correlation between the two variables is apparent. The concept of decoupling is widespread in the literature.

The other approach, so-called net export analysis, is less well-known than decoupling analysis and the methodology attempts to analyse a different phenomenon. There is an ever-increasing interest in economic analysis, identifiable also at the policy level that assesses the possibility of whether stringent environmental policies, which can either be expressed as strict environmental regulation or application of market-based instruments, such as taxes and trading schemes, will lead to the relocation of domestic industries, in particular when such policies are implemented unilaterally[2]. This subject matter belongs under the topic the pollution haven hypothesis (PHH) in the economic literature. The phenomenon involved here may be interpreted as an indicator of competitiveness as it can be stated that domestic industries - as a consequence of stringent environmental policies - relocate to foreign countries as they lose their competitive advantage over time. However, measurement of ‘stringency of environmental policies’ is definitely not a trivial task, and is discussed in the economic literature at some length (see for example Smarzynska and Wei, 2001).

Application of decoupling analysis is rather straightforward; this requires determination of the economic and environmental performance of various variables over time. On the contrary, analysis of the PHH is rather problematic and complex as a detailed analysis would require a detailed simulation modelling approach analysing the trade-economic-environment system at the global level. Such an approach is not pursued in this paper. Here, a more simple approach is applied, which cannot ultimately verify or reject the PHH, but which assesses the economic performance of selected sectors by analysing the trends in net exports expressed as a proportion of domestic consumption. Underlying the net export analysis are an examination of the specialisation patterns for the identified economic sectors and whether domestic consumption is met by domestic industries or whether an increasing share of domestic consumption has to be satisfied via an increase in imports. Occurrence of the latter indicates that the country in question is reducing specialisation in this economic sector relative to its consumption. However, it must be clearly stated that the net export analysis cannot provide any indication of whether the relocation of industries or economic sectors actually takes place and, even more importantly, it cannot determine the actual reasons underlying the relocation process[3].

In the last part of this paper the discussion with regard to the pollution haven hypothesis is extended in the sense that the topic of foreign direct investment (FDI) is discussed. A precondition for the relocation of industries is FDI, as the establishment of new production capacity in foreign countries is necessary. Identification of the underlying reasons for FDI is a challenging task, in particular determining whether the introduction of specific carbon-energy taxes in developed countries may trigger such a move. To the authors’ knowledge, only a very limited number of studies have studied the issue of linking environmental

[2] It has to be stated that the term ‘relocation of domestic industries’ may have two different meanings as relocation can mean the closure of capacity in the home country and investment in new capacity in a foreign country (i.e. relocation of a plant) or reallocating capacity utilisation between existing plants in different countries (i.e. relocation of production).
[3] An analytical framework linking the concepts of decoupling, competitiveness (as measured by the net export ratio) and carbon leakage is provided in Annex 1.

taxes with FDI. No study has been found which takes the additional step of assessing whether the implementation of environmental tax reform in EU member states led to the relocation of industries.

2. Decoupling analysis

In recent years decoupling analysis has come to represent a standard tool for studying economy-environment interactions. The methodology attracted additional attention in 2001 as the OECD adopted decoupling of environmental pressure from economic growth as one of the policy objectives of the OECD Environment Strategy for the First Decade of the 21st Century (OECD, 2002).

The basic idea behind the concept of decoupling may be referred to as 'breaking the link between "environmental bads" and "economic goods". In particular, it refers to the relative growth rates of a pressure on the environment and of an economically relevant variable to which it is causally linked (OECD, 2002, p.11)'. The rationale of the concept is to indicate the relationship between the driving force and the pressure of the Driving Force-Pressure-State-Impact-Response framework as promoted by international organisations, such as the OECD and EEA. It shows the change in environmental pressure, such as energy consumption, as compared to the evolution of the driving force, i.e. an economic variable such as GDP, over a predetermined period. The approach for measurement of decoupling most often used is to apply decoupling indicators with an environmental pressure variable as the numerator and an economic variable as the denominator. This analysis examines decoupling at the sectoral level and uses energy consumption and CO2 emissions as the environmental pressure variables – both expressed in physical terms – and production and consumption of the different sectors as the economic variables – expressed in monetary units at constant 1995 prices[4].

The analysis is based on data compiled as part of the COMETR project, presenting the results with regard to the evolution of eight sub-sectors (3-digit NACE classification)[5] of seven EU member states[6] during the time period 1995-2002. During this time period major ETRs have been implemented in six of these countries[7]. Furthermore, the approach used in this report applies 'decoupling factors' following an approach promoted by the OECD, and which is discussed in Box 1 below.

[4] Data used in the analysis have been collected as part of the COMETR project. The institutions involved in the data compilation process were: NERI (Denmark), PSI (UK), wiiw (Austria) and IEEP (Czech Republic).
[5] The sectors are 'meat and meat products' (sector 15.1), 'paper and paper products' (sector 21.2), 'basic chemicals' (sector 24.1), 'pharmaceuticals' (sector 24.4), 'glass and glass products' (sector 26.1), 'cement, lime and plaster' (sector 26.5), 'ferrous metals' (sector 27.1-3) and 'non-ferrous metals' (sector 24.4).
[6] The EU member states to be studied in more detail are: Denmark, Finland, Germany, the Netherlands, Slovenia, Sweden and the UK. Slovenia is included in the study although it has not implemented an ETR. However, it implemented in the 1990s a carbon tax.
[7] See for a detailed analysis: Speck, 2006.

Box 1: Decoupling indicator – the calculation of the decoupling factor

To compare decoupling among countries, the ratio of value of the decoupling indicator at the end and the start of a given time period is defined as follows: Decoupling ratio= $(EP/DF)_{\text{end of period}} / (EP/DF)_{\text{start of period}}$ with EP – environmental pressure variable, i.e. energy consumption or CO2 emissions, and DF – driving force, i.e. the economic variable, such as GDP or sectoral production output or consumption[8]. It can be concluded that decoupling has occurred during the period if the decoupling ratio is less than 1. However, the ratio does not indicate whether decoupling was absolute or relative. In addition the decoupling ratio can be converted into a decoupling factor[9]: Decoupling factor = 1 – decoupling ratio The decoupling factors (presented in Tables 1, 2 and 3 below) are positive in the presence of decoupling with a maximum value of 1 in cases when environmental pressure reaches zero. A decoupling factor of zero or negative states that no decoupling occurred during the period analysed.

Source: OECD, 2002

Application of the decoupling factor poses a problem as it does not allow *absolute* decoupling to be distinguished from *relative* decoupling. *Absolute* decoupling refers to a situation in which the environmental pressure variable shows either a stable or decreasing trend in relation to a growing trend with regard to the economic variable. In contrast, relative decoupling denotes a development where the growth rate of the environmental pressure variable is positive but smaller than the growth rate of the economic variable (OECD, 2002). This aspect of the decoupling analysis is shown in detail in Annex 2 of this paper.

Table 1: Decoupling factor: energy consumption and output of economic sectors in EU member states during the period 1995-2002 (output measured in 1995 prices[10])

	sector 15.1	sector 21.2	sector 24.1	sector 24.4	sector 26.1	sector 26.5	sector 27.1-3	sector 27.4	decoup, occurred
UK	0.31	0.11	-0.07	0.04	0.23	0.48	-0.07	-0.20	5/8
DE	0.38	0.14	0.11	0.16	0.02	-0.04	-0.11	0.12	6/8
DK	0.00	-0.16	0.06	0.27	-0.61	0.15	-0.39	0.19	5/8
NL	-0.29	-0.22	-0.05	0.44	-0.04	0.12	0.01	-0.16	3/8
FI	-0.16	0.07	0.12	0.32	0.22	n.a.	-0.22	-0.12	4/7
SE	0.24	-0.47	n.a.	0.29	0.30	-0.19	-0.24	-0.08	3/7
SI	-0.45	-0.28	-0.32	-0.56	0.12	-0.34	-0.23	-0.15	1/8

Note: DK - time period is 1995-2001 for all sectors; FI – time period is 1995-2000 for sectors 21.2, 24.4, 26.1, 27.1-3 and 27.4; NL – time period is 1995-2000 for sectors 26.5, 27.1-3 and 27.4.

Source: Author's own calculation based on COMETR database – work package 3

[8] The ratio EP/DF is interpreted as unit environmental pressure in the analytical framework in Annex 1.
[9] The decoupling factor is equal to the percentage change in unit environmental pressure – see Annex 1.
[10] All monetary figures were adjusted to 1995 prices by using national GDP deflators.

The decoupling factors for energy consumption relative to production are provided in Table 1.The results do not show consistent developments between sectors and countries. Nevertheless, the overall picture shows that decoupling between energy consumption and output occurred in the majority of the countries. Decoupling is not evident in at least two economic sectors in each of the countries analysed. An exception is the situation in Slovenia where it can be stated as a general rule that decoupling does not take place, i.e. decoupling is revealed only in a single sector.

The data used in this study indicate that decoupling between output and energy consumption occurred most frequently in Germany, i.e. in six of the eight sectors. The UK data show a decoupling trend in five of the eight sectors, and in Denmark and Finland a decoupling can be reported from four of the eight (seven) sectors analysed. The Netherlands and Sweden are ranked last as the data show that decoupling took place only in three out of the eight (seven) sectors.

There are two sectors which are of particular interest: decoupling occurred in sector 24.4 ('pharmaceuticals') in all six 'old' EU member states, whereas in sector 27.1-4 ('ferrous metals') the data indicate that decoupling only occurred in the Netherlands during the period analysed.

Decoupling factors can also be calculated by using sectoral CO_2 emission as the environmental pressure variable, as has been carried out in Table 2.

Table 2: Decoupling factor: CO_2 emissions and output of economic sectors in EU member states during the period 1995-2002 (output measured in 1995 prices)

	sector 15.1	sector 21.2	sector 24.1	sector 24.4	sector 26.1	sector 26.5	sector 27.1-3	sector 27.4	decoup, occurred
UK	0.29	0.04	0.17	0.23	0.30	0.55	-0.10	-0.02	6/8
DE	0.20	0.14	-0.08	0.17	0.04	-0.02	-0.10	0.15	5/8
DK	0.11	-0.01	0.17	0.40	-0.43	0.15	-0.19	0.35	5/8
NL	-0.24	-0.23	-0.08	0.40	0.06	0.12	0.02	-0.07	4/8
FI	-0.04	0.18	0.19	0.43	0.30	n.a.	-0.21	-0.05	4/7
SE	0.35	-0.12	n.a.	0.56	0.41	-0.17	-0.33	0.12	4/7
SI	-0.28	-0.26	-0.30	-0.53	0.13	-0.49	-0.32	-0.14	1/8

Note: DK - time period is 1995-2001 for all sectors; FI – time period is 1995-2000 for sectors 21.2, 24.4, 26.1, 27.1-3 and 27.4; NL – time period is 1995-2000 for sectors 26.5, 27.1-3 and 27.4

Source: author's own calculation based on COMETR database – work package 3

Table 2 shows the decoupling factors for carbon emissions relative to output. The overall findings as presented in Table 2 are comparable to the results in Table 1 in that decoupling occurred in the majority of the sectors and countries studied. The fascinating aspect of this comparison is the fact that changes in the energy mix can provide some rather interesting insights. For example, the decoupling factors of sector 24.1in the UK indicate that no decoupling occurred when analysing energy consumption versus output, but decoupling between the CO2 emission and output took place. This means that the energy mix of this sector must have changed and a move away from CO2 intensive energy products to less CO2 intensive energy products has taken place.

The results are not in accordance with the findings of a recent report published by Eurostat analysing the economic and environmental performance of the manufacturing industries in EU member states (Eurostat, 2006). It must be stated that the coverage and variables are also slightly different from those used in the current paper. For example, the Eurostat report concludes that an absolute decoupling between gross value added and greenhouse gas emissions occurred in the metals sector (divisions 27 and 28) at the EU 15 level. We find that inverse decoupling between output and CO2 emissions occurred in the majority of the six old EU member states during the same period. Differences in the results are not unexpected as, on the one hand, different variables are used (i.e. energy consumption and / or CO2 emissions as opposed to greenhouse gas emissions as the environmental pressure variable, and total output versus value added as the economic variable) and, on the other, the approach used in this paper is more sectoral than that used by Eurostat. Our results also slightly differ from the Nordic Council report ‘Decoupling of CO2 Emissions from Energy Intensive Industries’ (Nordic Council, 2006) as, also here, there are differences in the variables and economic sectors selected in the two analyses, as well as the time periods analysed.

The concept of decoupling is regularly seen as a measure to assess the decoupling of environmental elements from production patterns as discussed above. However, the OECD Environment Strategy states that ‘decoupling environmental pressures from economic growth requires an integrated effort to address consumption and production patterns’ (OECD, 2002, p.9). Therefore, the decoupling analysis here is extended by considering consumption as the economic variable and the evolution is measured in a second decoupling analysis between energy consumption, followed by use of CO2 emissions as the environmental pressure variable and consumption as the economic variable. The results are presented in Tables 3 and 4 and, not surprisingly, some differences are apparent in relation to the findings in Tables 1 and 2.

Table 3: Decoupling factor: energy consumption and total consumption of economic sectors in EU member states during the period 1995-2002 (consumption measured in 1995 prices)

	sector 15.1	sector 21.2	sector 24.1	sector 24.4	sector 26.1	sector 26.5	sector 27.1-3	sector 27.4	decoup, occurred
UK	0.39	0.13	-0.19	0.14	0.26	0.49	0.00	-0.16	6/8
DE	0.30	0.14	0.13	0.31	-0.06	-0.18	-0.21	0.00	5/8
DK	-0.70	-0.18	-0.35	0.40	-0.49	0.56	-0.42	0.22	3/8
NL	-0.17	-0.33	0.09	0.41	n.a.	n.a.	-0.15	0.02	3/6
FI	n.a.	n.a.	n.a.	0.33	n.a.	n.a.	-0.31	-0.24	1/3
SE	0.30	-0.30	n.a.	0.16	0.37	-0.21	-0.34	-0.22	3/7
SI	-0.46	-0.23	-0.12	n.a.	0.40	-0.28	-0.32	-0.03	1/7

Note: DK - time period is 1995-2001 for all sectors; FI – time period is 1995-2000 for sectors 21.2, 24.4, 26.1, 27.1-3 and 27.4; NL – time period is 1995-2000 for sectors 26.5, 27.1-3 and 27.4

Source: author’s own calculation based on COMETR database – work package 3

The results show that in four sectors no decoupling occurred when consumption, rather than production, is used as the economic variable: sector 26.1 (‘glass and glass products’) in Germany; sector 15.1 (‘meat and meat products’) in Denmark; sector 24.1 (‘basic chemicals’) in Denmark, and sector 27.1-3 (‘ferrous metals’) in the Netherlands. The consumption-based decoupling analysis shows the occurrence of decoupling in three sectors, as opposed to no decoupling in production based analysis. Two of the sectors are in the Netherlands, sector 24.1 (‘basic chemicals’) and sector 27.4 (‘non-ferrous metals’), and the last one is sector 27.1-3 (‘ferrous metals’) in the UK.

Table 4 reveals the findings of the decoupling analysis using CO2 emissions and total consumption. As expected the results differ slightly from those presented in Table 3, and are in line with the results in Table 1 and 2.

Table 4: Decoupling factor: CO2 emissions and total consumption of economic sectors in EU member states during the period 1995-2002 (measured in 1995 prices)

	sector 15.1	sector 21.2	sector 24.1	sector 24.4	sector 26.1	sector 26.5	sector 27.1-3	sector 27.4	decoup, occurred

UK	0.38	0.07	0.07	0.31	0.33	0.56	-0.03	0.01	7/8
DE	0.10	0.14	-0.05	0.31	-0.03	-0.16	-0.20	0.03	4/8
DK	-0.51	-0.03	-0.19	0.50	-0.32	0.56	-0.22	0.38	3/8
NL	-0.13	-0.35	0.06	0.37	n.a.	n.a.	-0.15	0.10	3/6
FI	n.a.	n.a.	n.a.	0.44	n.a.	n.a.	-0.30	-0.17	1/3
SE	0.40	0.01	n.a.	0.48	0.47	-0.18	-0.43	0.01	4/7
SI	-0.29	-0.21	-0.10	n.a.	0.41	-0.41	-0.42	-0.02	1/7

As shown in Annex 1, the difference between the results in Table 3 and 4 reveals the percentage changes in the emission factors, and these are presented in Table 5. Table 5 provides an indication of the decoupling between CO2 emissions and energy use.

Table 5: Percentage change in the emission factors – difference between Tables 3 and 4 (see Annex 1)

	sector 15.1	**sector 21.2**	**sector 24.1**	**sector 24.4**	**sector 26.1**	**sector 26.5**	**sector 27.1-3**	**sector 27.4**
UK	0.01	0.06	-0.26	-0.17	-0.07	-0.07	0.03	-0.17
DE	0.2	0	0.18	0	-0.03	-0.02	-0.01	-0.03
DK	-0.19	-0.15	-0.16	-0.1	-0.17	0	-0.2	-0.16
NL	-0.04	0.02	0.03	0.04	n.a.	n.a.	0	-0.08
FI	n.a.	n.a.	n.a.	-0.11	n.a.	n.a.	-0.01	-0.07
SE	-0.1	-0.31	n.a.	-0.32	-0.1	-0.03	0.09	-0.23
SI	-0.17	-0.02	-0.02	-0.04	-0.01	0.13	0.1	-0.01

Source: author's own calculation based on COMETR database – work package 3

Application of consumption as the economic variable, i.e. as the driving force, in a decoupling analysis may appear unusual as production or value added are more frequently used as the economic variable. However, unit environmental pressure and the decoupling factors were deliberately defined in terms of consumption (rather than production). There are several reasons for this:

- As decoupling relates to the divergence between changes in economic well-being and changes in environmental quality, it is more intuitive (and theoretically justifiable) to measure economic activity in terms of consumption – from which utility is derived.
- The use of consumption as the economic variable makes the decoupling factor more relevant to the analysis of international trade and the environment.
- If production is used, then there is no difference between unit environmental pressure and emissions / energy intensity, and hence the decoupling factor is merely equal to the percentage change in energy intensity – in which case there does not seem much point in using it as a separate indicator!
- Finally, the use of consumption allows the decoupling factor to be linked to changes in the net export ratio (see section 3 below).

Summary

Decoupling is a straightforward approach for analysing trend patterns between environmental pressure variables and economic variables. However, the simplicity of the approach also has some clear drawbacks as, for example, the causes and effects linked to the appearance or non-appearance of decoupling are completely ignored. Decoupling provides an *ex post* analysis of trends, but cannot offer any explanation of the underlying factors which cause the trend to occur. Furthermore, decoupling is often used in the analysis of domestic trends but not in the analysis of environment and trade issues, which are becoming more and more interesting, in particular in the context of discussions associated with competitiveness. Furthermore, any more detailed environmental considerations, such as the environment's capacity to sustain, absorb or resist environmental pressures (for example CO_2 emissions), are not taken into account.

The analysis described in this paper shows an inconsistent development between sectors and countries apart from in Slovenia where decoupling is the exception rather than the rule. Decoupling occurred in the majority of the sectors in the UK and Germany. It is also interesting to note that there is almost no difference in the results when consumption is used as the economic variable for these two countries. This contrasts to the situation in the other countries, where decoupling occurred in fewer sectors when the consumption variable was applied in the analysis. However, the results on the whole have to be seen in light of that a rather short time period has been used in the analysis, ignoring the developments of the early 1990s.

One shortcoming, namely the focus lying mainly on the individual country-specific developments of the energy-environment interactions, can be offset when using consumption data as the economic driver. This method extends the commonly used decoupling approach, which is generally defined and measured in production terms but which is of limited use when analysing international trade and environment. Furthermore, it has to be remembered that 'production is conditioned and determined by consumption patterns.' (Muradian et al., 2002, p.52)

3. Leakage analysis

3.1 Introduction

The interest in international trade and its environmental consequences has been increasing during recent decades and the topic is currently high on the political agenda. The reasons for this interest are manifold, because international trade is highly significant 'as a factor of economic development in a context of increasing globalization' (Mongelli et al., 2006, p.88). The subject is also important in the framework of climate policy issues, foreign direct investments (FDI) and, thereby, in the analysis of the relocation of domestic industries. This section of the report attempts to analyse topics surrounding the pollution haven hypothesis (PHH) in relation to carbon leakage.

The carbon leakage debate has become very prominent in recent years, in particular in the context of climate change policy, as it refers to the fact 'that a part of the CO_2 reduction that is achieved by countries that abate CO_2 emissions is offset by an increase in CO_2 emissions in non-abating countries' (Sijm et al., 2004, p.11). The motivation for analysing carbon leakage is based on the fact that countries are implementing policies, such as carbon-energy taxation as well as trading schemes aiming to abate CO_2 emissions, and that these policies may lead to an increase in CO_2 emissions in countries which do not implement such policies. This approach implies a form of causality. Although it is straightforward and relatively easy to check whether the reality indicates such a development, it is rather difficult to assess satisfactorily whether the increase in CO_2 emissions in countries not actively implementing policies aiming to reduce CO_2 emissions is the consequence of the policies implemented in abating countries or whether other factors determine such an increase (see, for a more detailed discussion, Sijm et al., 2004).

Various consequences of international trade for the environment are recognisable and these can have positive as well as negative environmental implications. Grossman and Krueger (1991) distinguish between the technical, scale, and composition effect of international trade. The technical effect is judged as positive towards the environment as it is seen 'as a response to the increased income that trade promotes, pollution policy is tightened, which spurs pollution reduction innovation/investment (Liddle, 2001, p.21)'. On the contrary, the scale effect influences the environment negatively as 'trade leads to an increase in the size of the economy, which tends to increase pollution (Liddle, 2001, p.21)'. The composition effect is, in the context of this paper, of significance as it is not obvious whether this leads to further environmental deterioration or implies environmental improvement. The composition effect is closely related to the pollution haven hypothesis (PHH)[11] and the pollution displacement hypothesis (PDH)[12].

The proponents of these hypotheses claim that low environmental standards are a source of comparative advantage influencing trade patterns and thereby leading to relocation of industries to countries with less stringent environmental standards. The underlying principle of the PHH is the existence of international trade and the fact that energy-intensive and pollution-intensive industries can move their production capacities from countries with stricter environmental regulations to countries with less stringent policies, and then still sell the products produced in foreign countries in their domestic market. The logical consequence of the PHH is the relocation of domestic industries, leading to a reduction of the economic performance of domestic industry, thereby leading to an increase in unemployment. Moreover, the environmental consequences at the global level are unclear in relation to the domestic level where the improvement in environmental quality occurs. The linkage between the PHH and foreign direct investment (FDI) as a necessary condition for building up production capacity in foreign countries is therefore evident.

It is regularly argued that the production technology used in countries to which industries are relocating is not as environmentally benign as in the domestic countries. However, this assumption is questioned in the literature for several reasons: multinational enterprises are applying the same technology all over the world, relocation of industries and public awareness, i.e. international NGOs are assessing and observing relocation quite carefully. Furthermore, there is a tendency for multinational companies to use the most recent technology at all production locations worldwide, as this approach reduces planning and maintenance costs (Oikonomou et al., 2006). This is also the result of a study undertaken by Ekeland and Harris (2003) in which they reveal that plants owned by multinational foreign companies in developing countries are more energy efficient than domestically owned plants and, in addition, that cleaner types of energy fuels, such as natural gas and electricity, are used.

The analysis of FDI flows between developed and developing countries undertaken by Letchumanan and Kodoma (2000) is interesting as the authors found no correlation between FDI flows and the pollution intensity of an industry for countries such as Singapore and Thailand, meaning that FDI taking place in the 1980s and 1990s was mainly in clean industries. Furthermore, the authors have studied outward FDI in developed countries and - based on their analysis - they conclude that: 'It is thus clear that more pollution intensive industries are moving among developed countries than to developing countries' (Letchumanan and Kodoma, 2000, p.66). This finding is rather interesting in the sense that it is not really in line with the PHH, in particular in the context of the EU, as environmental regulations are becoming more and more established at the EU level as they have to be transposed into national legislation, and are therefore rather similar between EU member states.

3.2 The net export analysis

It has to be stated that an analysis of the PHH is not presented in this paper but we attempt to:

- shed some light on trends of the economic performance of economic sectors in OECD countries
- study more disaggregated economic sectors of those EU member states which introduced an ETR during the last fifteen years in more detail.

[11] The 'race-to-the-bottom' hypothesis is sometimes seen as a synonym for the pollution haven hypothesis by some scholars (for example Smarzynska and Wei, 2001).
[12] It is understood under the pollution displacement hypothesis (PDH) that trade liberalisation will lead to an increase of pollution-intensive industries in developing countries as developed countries will implement even stricter environmental regulations (see Liddle, 2001). The PDH is not discussed in more detail in this report.

The approach used is to examine and compare changes in the consumption and net export patterns of different economic sectors. Net export measures as a proportion of domestic consumption are used as an indicator in this approach[13].

The basic idea behind the net export analysis is to calculate an indicator measuring a country's net export with the world (or other countries depending on data availability) as a proportion of the country's consumption from the selected economic sector (Cole, 2004). If the indicator shows a declining trend over time then it may be argued that the domestic demand for products is satisfied via an increase in imports of these products[14]. Therefore it may be concluded – as in the economic literature - that relocation took place[15], i.e. the commodity has been produced in foreign countries and imported so that domestic demand is satisfied – and it is regularly assumed that this means that the pollution haven hypothesis is valid (Cole, 2004 and Mongelli et al., 2006).

This analysis is clearly not able to verify or reject the PHH, but it can provide some interesting insights. A declining trend of the indicator may confirm the PHH as it may be assumed that an increasing part of domestic demand is satisfied via an increase in imports from other countries. But a more meaningful indicator is definitely import intensity and the way in which this indicator evolves over time.

Our analysis is based on two different datasets: the OECD STAN database (Section 3.2.1) and the dataset compiled as part of the COMETR project (Section 3.2.2). The former database is not as detailed, i.e. only data for economic sectors according to NACE 2-digit classification, as the COMETR database, but it includes data for all OECD countries. Moreover, it only provides data for total export and import. In contrast, the COMETR dataset offers data for economic sectors of NACE 3-digit classification, and it differentiates between EU and non-EU exports and imports[16].

Net exports as a share of consumption (*NetX*) are calculated using the straightforward formula:

$NetX_{kt} = (X_{kit} - M_{kit}) / C_{kt}$

with $C_{kt} = Y_{kt} + M_{kt} - X_{kt}$

Where *X, M, C* and *Y* represents export, import, consumption and production, respectively, of commodity (sector) *k* to country *i* (*i*=EU member states or non-EU member states) and time period *t*.

3.2.1 The evolution of net exports at the OECD level

As expected the development of the indicator is not consistent between the OECD countries presented in the figures below. A decreasing trend of the ratio net export -consumption is found for Finland, Hungary, Japan, Sweden, UK and the US. It can therefore be concluded that the trend shows that an increase in imports is required to satisfy domestic consumption. The trend of the net export ratio is shown for five different economic sectors for the period 1990-2003 in Figures 1 to 5.

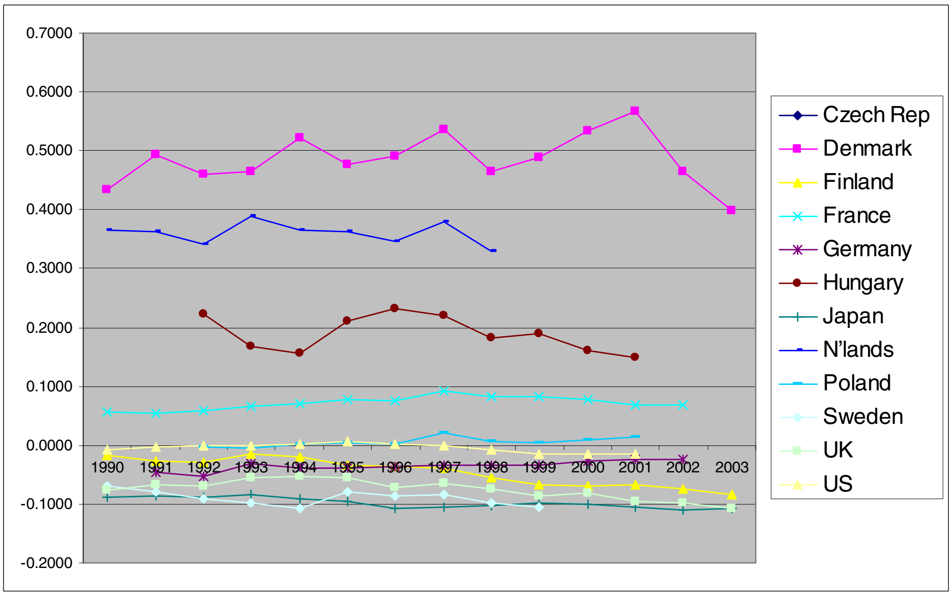
[13] See also the papers from Cole, 2004 and Mongelli et al., 2006 who are using this approach assessing trade patterns between USA, UK, Japan, Latin America, Asia (Cole, 2004) and the trade patterns of Italia (Mongelli et al., 2006).

[14] As discussed in Annex 1 in more detail a declining trend does not necessarily provide a clear indication of the extent to which domestic demand is satisfied by an increase in import. Import intensity is clearly a more useful indicator in this context as it indicates the extent to which domestic demand is satisfied by foreign products.

[15] A declining net export ratio does not necessarily imply that there has been a relocation of production capacity. It does not even necessarily imply that there has been a reduction in the country's share of global production. See the discussion in Annex 1.

[16] EU data refers to the old EU 15 member states.

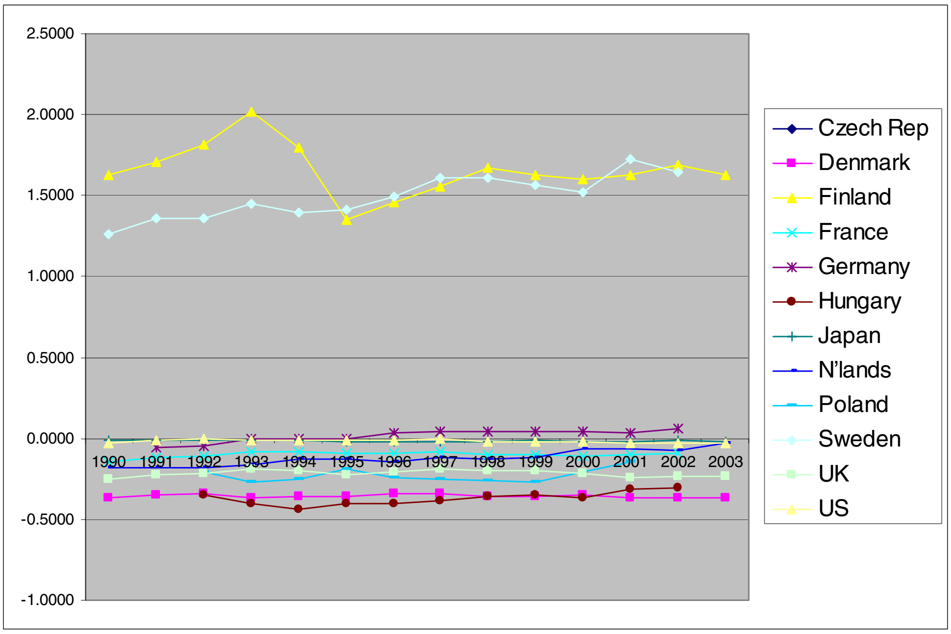
Figure 1: Trend of net export as a proportion of domestic consumption of sector 15 ('food products and beverages')



Source: OECD STAN database and author's own calculation

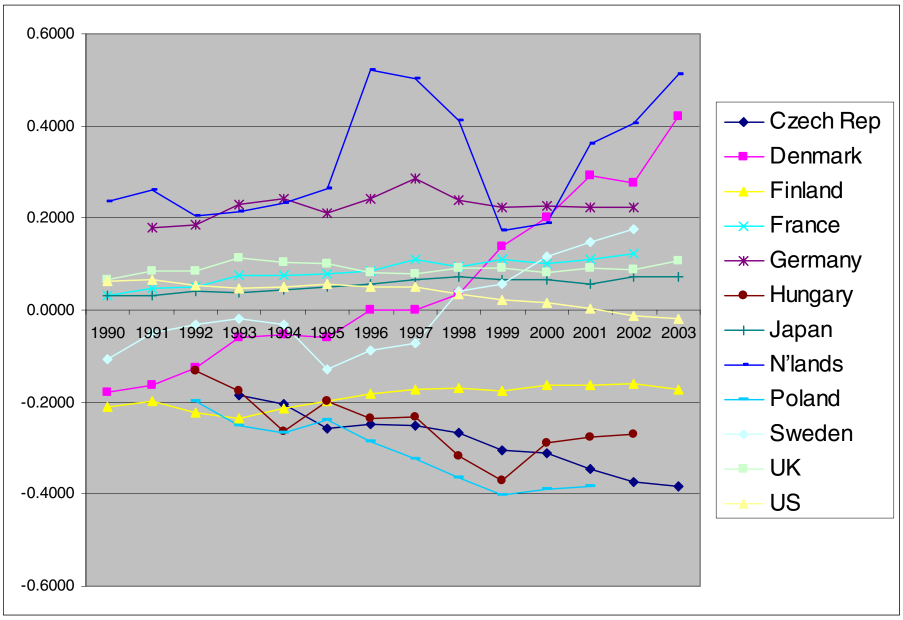
Figure 2 presents the results of the net export analysis for sector 21 ('pulp, paper and paper products') clearly illustrating the importance of this sector for the Swedish economy and partly for Finnish economy. In case of Sweden the increasing trend of the indicator explains the significance of this economic sector and it can be stated that the PHH is rejected.

Figure 2: Trend of net export as a proportion of domestic consumption of sector 21 ('pulp, paper and paper products')



Source: OECD STAN database and author's own calculation

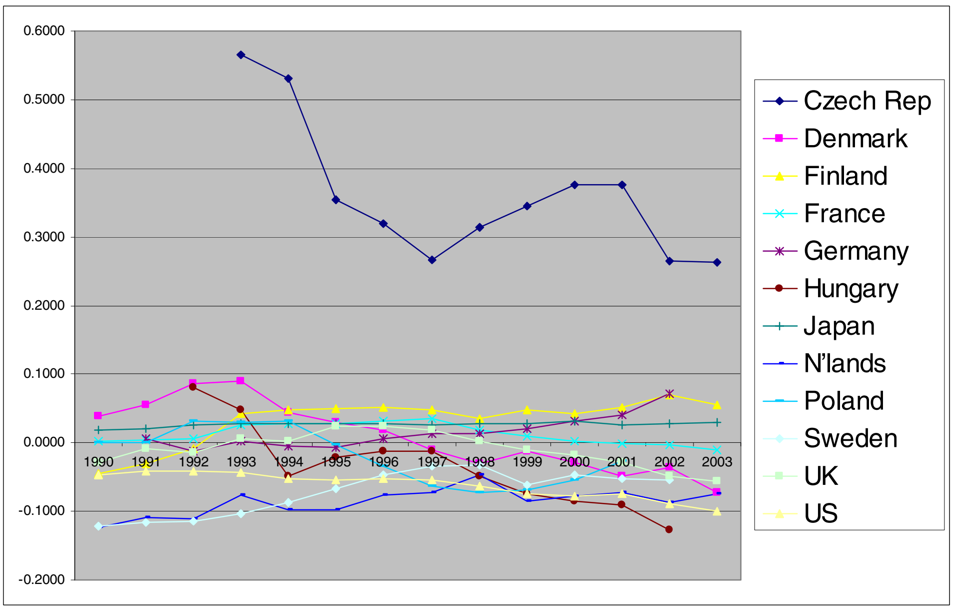
Figure 3: Trend of net export as a proportion of domestic consumption of sector 24 ('chemicals and chemical products')



Source: OECD STAN database and author's own calculation

Large differences between the developments in OECD countries can be observed in sector 24 ('chemicals and chemical products'). During the period between 1990 and 2003 an increasing trend is identified in many European OECD countries, such as Denmark, Finland, France, Germany, Netherlands, Sweden and the UK as well as in Japan. However, a decreasing trend is found in the new OECD member states, the Czech Republic, Hungary and Poland, as well as in the US. The declining trend for the three European countries can probably be attributed to the growth of their economies and that the domestic consumption was increasing faster than domestic production so that imports have to satisfy domestic consumption to a larger degree.

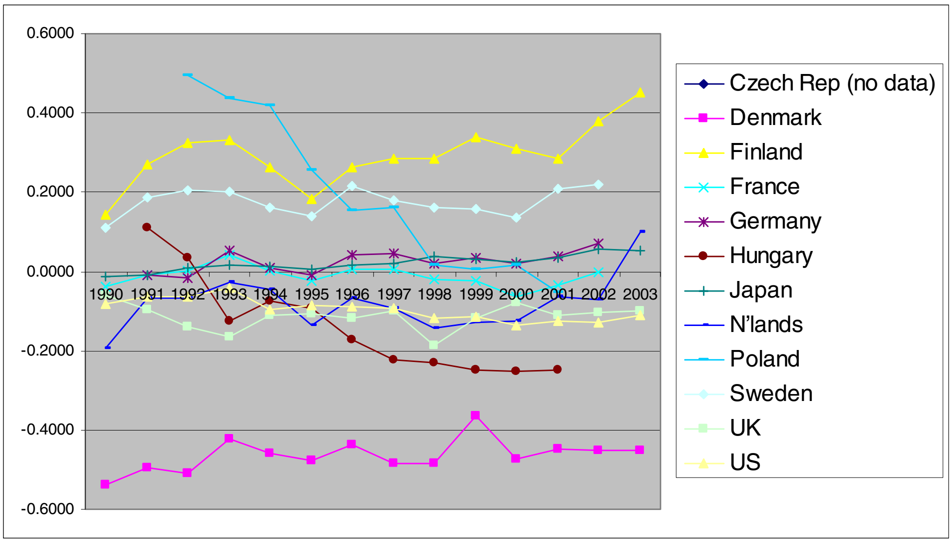
Figure 4: Trend of net export as a proportion of domestic consumption of sector 26 ('other non-metallic mineral products')



Source: OECD STAN database and author's own calculation

We find again an increasing trend for Finland, Germany and Sweden when determining the net export ratio in sector 26 ('other non-metallic mineral products') as compared to decreasing trends in Denmark, Hungary, UK and US.

Figure 5: Trend of net export as a proportion of domestic consumption of sector 27 ('basic metals')



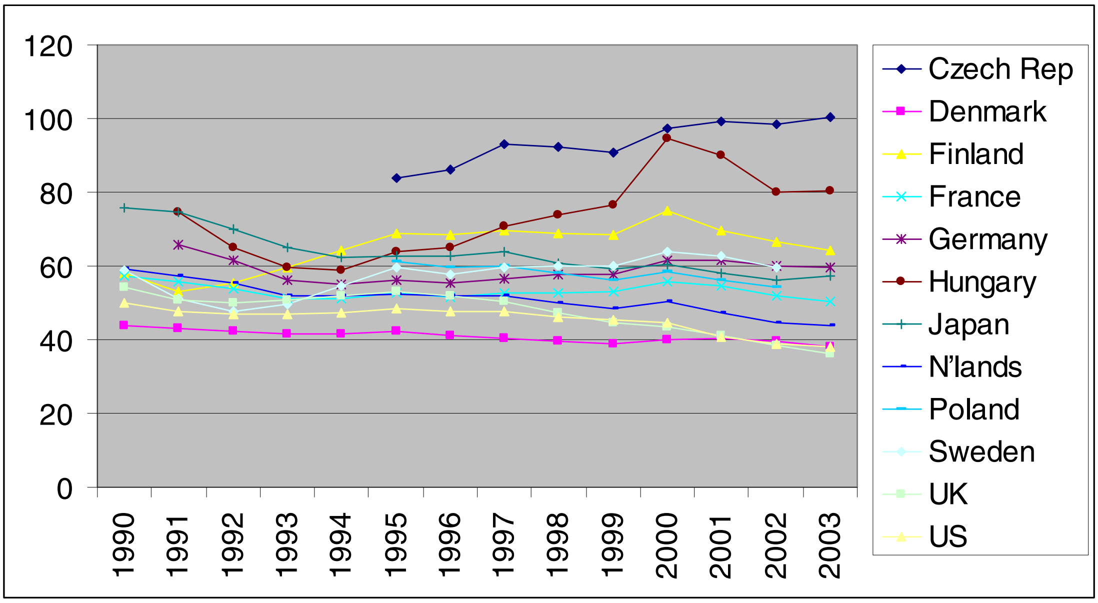
Source: OECD STAN database and author's own calculation

The decrease in the net export ratio of sector 27 ('basic metals') in Poland and Hungary is most obvious in Figure 5. Apart from these two countries a decreasing trend is also found in the UK and US. The data show the exact opposite development for four European countries (Finland, Denmark, Netherlands, Germany), meaning that the share of domestic production satisfying domestic consumption has increased during the period studied.

It can be concluded that the analysis of the net export ratio shows some interesting results, but at the same time it does not give any indication whether there was relocation of industries as a consequence of the stringency of environmental regulation. It is worthwhile to mention that an increasing trend in the net export ratio has been calculated in countries, such as Denmark, Finland, German, the Netherlands and Sweden, which have implemented environmental tax reforms (ETRs) during the period studied. This result implies that demand in these countries has been satisfied via domestic production and from this it can be derived that the competitiveness of the industry in those countries has not been negatively affected by the ETR based of the findings of the net export analysis.

This analysis only shows increases in imports. But the causes for the increase of the imports are not assessed and there can be a whole range of different reasons for this development. The data show a decreasing trend in the net export analysis for some of the sectors of the three economies in transition (Czech Republic, Hungary and Poland) as well as for the UK and the US. As discussed above a decreasing trend may imply that domestic demand is increasingly met by imports. However the reason for this development is different as Figure 6 clarifies. The importance in terms of the contribution of the manufacturing industry to GDP is increasing in the Czech Republic and Hungary as compared to the UK and the US, where an obvious trend towards a service economy can be found as the ratio between the output of the manufacturing industry and GDP is falling. This share is also falling in other OECD countries (Denmark, Finland, France, Japan and the Netherlands) but the decrease is more strongly pronounced in the two former countries in the period between 1995 and 2003. A rather interesting evolution occurred in Germany where this share increased which is in strong contrast to all other 'old' OECD member states.

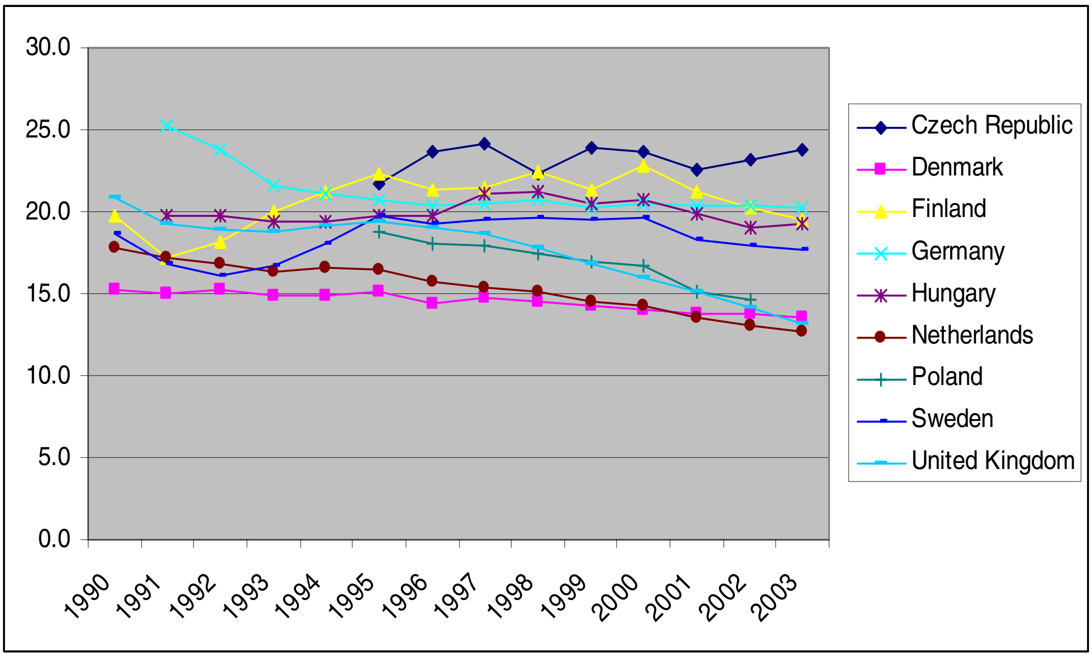
Figure 6: Share of output of manufacturing industry to GDP in OECD countries



Source: OECD STAN database

It is also worthwhile to review the importance of the manufacturing industry by measuring the evolution of the value added generated by the manufacturing industry as a share of GDP (see Figure 7). The development paths shown in the figure below are not consistent but the overall trend is, as the importance of the manufacturing industry in 2003 declined in relation to 1990, and since has declined further. The decline can be seen in the UK over the period as a whole in contrast to the situation in Finland and Sweden where the significance of the manufacturing industry increased in the mid to late 1990s but dropped thereafter. It should be mentioned in this context that during the 1990s these two countries implemented ETRs and increased the carbon energy tax rates levied on energy consumed by manufacturing industries. The only exception is the Czech Republic where this share increased between 1995 and 2003.

Figure 7: Evolution of value added of manufacturing industry as % of GDP in selected EU member states



Source: OECD STAN database, Eurostat and author's own calculation

There are still some differences between some of the EU member states recognisable although the evolution is rather similar. The biggest drop in this share can be found in the UK (1990: 20.9 and 2003: 13.2) followed by the Netherlands. In contrast the share remained almost constant in Finland, Germany and Sweden.

3.2.2 A detailed analysis of net exports of EU member states

The section above compared net export of individual OECD countries with the rest of the world indicating that consumption plays a significant role in this analysis. It is clear that this net export approach cannot explain whether specialisation of domestic industry occurred or whether relocation of domestic industry took place. This type of analysis is not suited and not planned for addressing the question of whether stricter environmental regulations led to a relocation of domestic industries. However, it presents the trend of net exports as a proportion of consumption and whether domestic production satisfied demand or whether an increasing part of demand has been satisfied with imports.

A slightly more detailed analysis of the net export analysis will follow, using data at the NACE three digit level, compiled as part of the COMETR project. This means that the analysis is based on data from the eight sub-sectors already discussed in Chapter 2 of this report (see also Section 2 in Annex 1 for a more detailed discussion on the concept).

The equation of net export can be rewritten as:

$$NetX = \eta = (X\text{-}M)/C = (Y/C - 1)$$

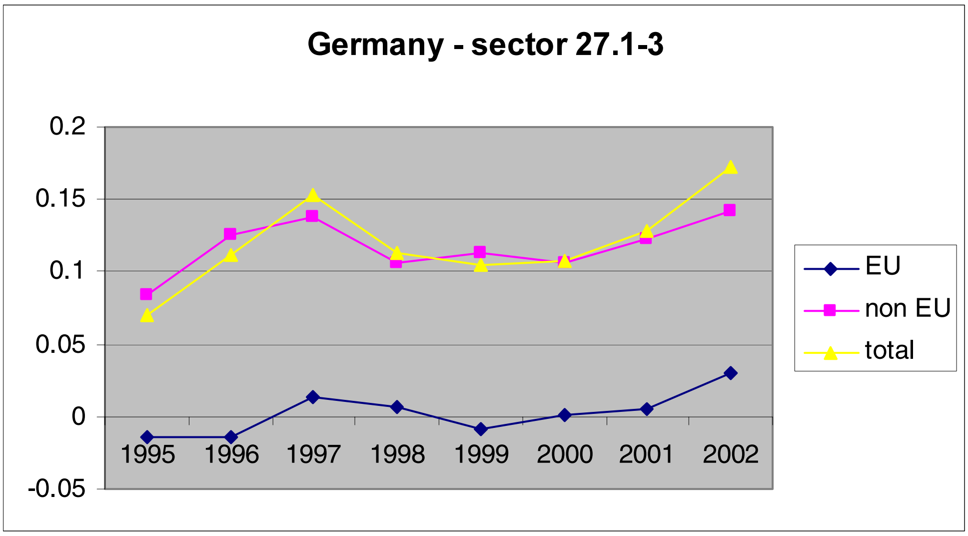
This formula puts production and consumption in direct connection. As discussed above the net export approach may be used to verify whether some changes in the economic structure of a country occurred assessing whether domestic consumption (C) is satisfied by domestic production (Y).

Therefore we can distinguish between the following cases:

- $\eta > 0$: i.e. $Y > C$ and η is increasing over time: this means that Y is increasing at a faster rate than C and this is an indication that exports X are growing faster than imports M, i.e. increase in net export figure. When using changes in net export as an indicator for competitiveness we may conclude that this is a sign for an increase in competitiveness of the specific sector[17]. Sector 27.1-3 in Germany shows this evolution (see Figures 8 and 9 below).

- $\eta < 0$: i.e. $Y < C$ (meaning negative net export i.e. imports $M >$ exports X) and η is increasing over time: this means that Y increases faster than C over time; i.e. exports X are increasing faster than imports M – net export is getting smaller (it could also be the case that change in export is constant but imports are decreasing). Again we may conclude that this situation is an indication for an increase of competitiveness (using changes in net export as the indicator) and no relocation of domestic industries occurred. Sector 15.1 in Germany shows this trend (see Figures 10 an 11 below).

Figure 8: Net export analysis of sector 27.1-3 ('ferrous metals' - Germany)



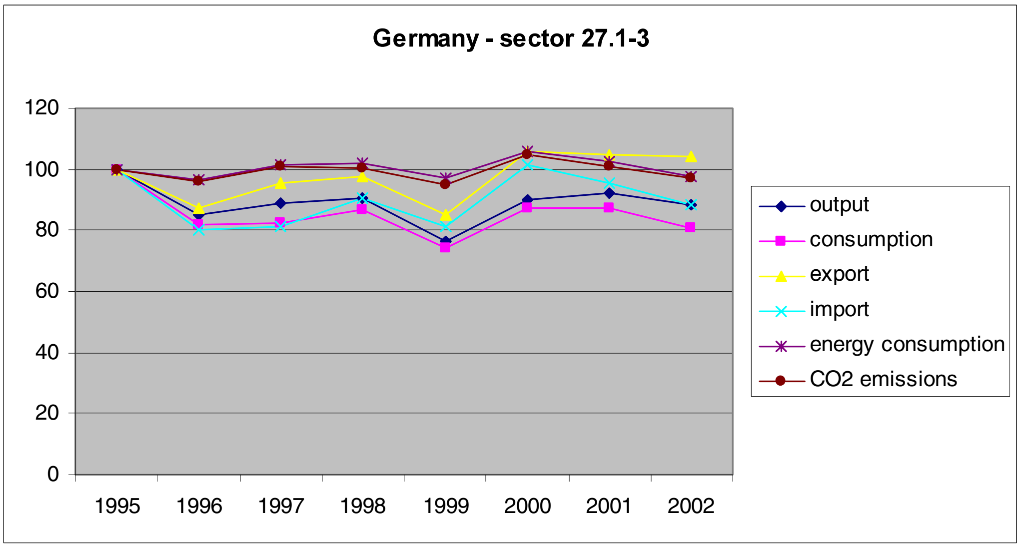
Source: COMETR database

The figure distinguished between net export to EU-15 countries (EU), to non-EU countries (non EU) and total trade (total)[18]. The evolution is the same for all three variables meaning that the German sector gain competitiveness with regard to all trading partners based on the findings of the net export analysis.

[17] It must be stated that this analysis is made at the sectoral level. However, NACE three digit sub-sectors are still rather heterogeneous, meaning that these findings may not completely correspond to the reality as some industries belonging to this sector may have lost competitiveness in accordance with the approach of net export analysis used in this report.

[18] It has to be stated that only the net export ratio (total) can be clearly interpreted. In contrast the differentiation of the net export ratio into EU and non EU is a bit arbitrary as it is not possible to derive the appropriate consumption values to make these indicators really meaningful. It would require to have the appropriate consumption values to be used as the denominator in the calculation for the two other ratios (EU) and (non EU).

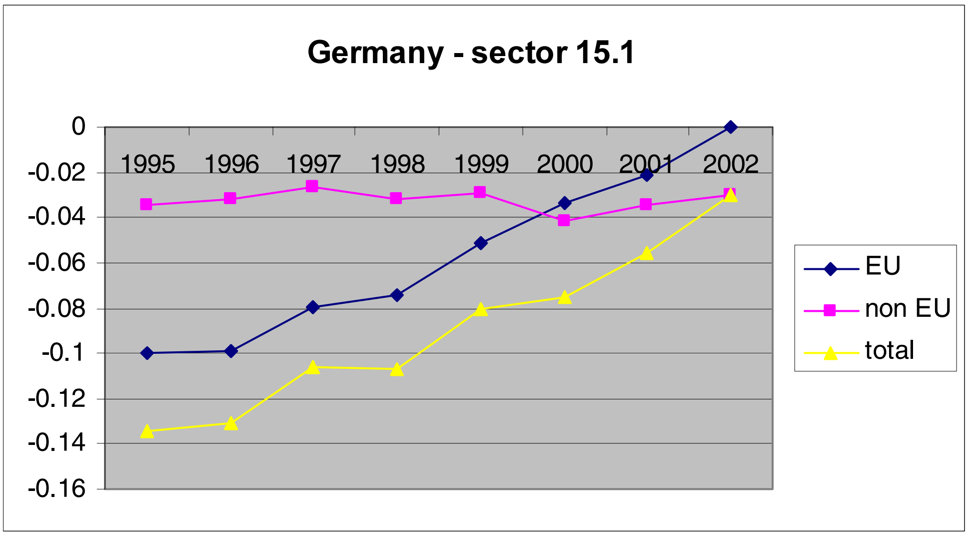
Figure 9: Evolution of key variables of sector 27.1-3 ('ferrous metals' - Germany) – all monetary figures are presented in 1995 prices)



Source: COMETR database

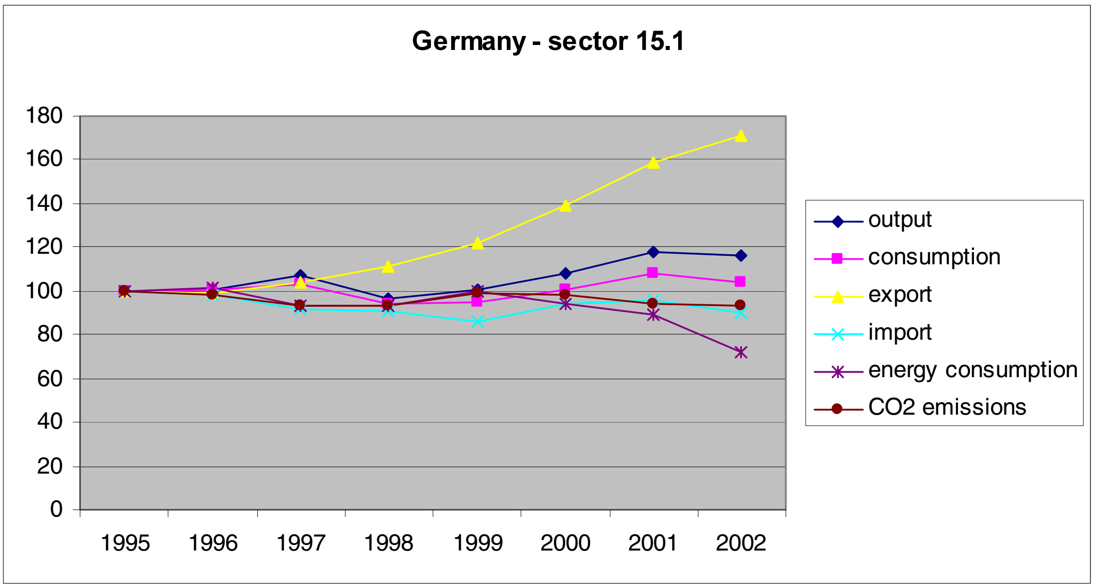
The evolution of some key variables is presented in Figure 9. The pattern of changes is the same for all variables shown in the figure. The graphs in this figure are also quite interesting as they verify the decoupling analysis, i.e. the real output of this sector falls by 12 percent as compared to a drop in energy consumption of only 2 percent during the period 1995-2003.

Figure 10: Net export analysis of sector 15.1 ('meat and meat products' - Germany)



Source: COMETR database

Figure 11: Evolution of key variables of sector 15.1 ('meat and meat products - Germany) – all monetary figures are presented in 1995 prices)

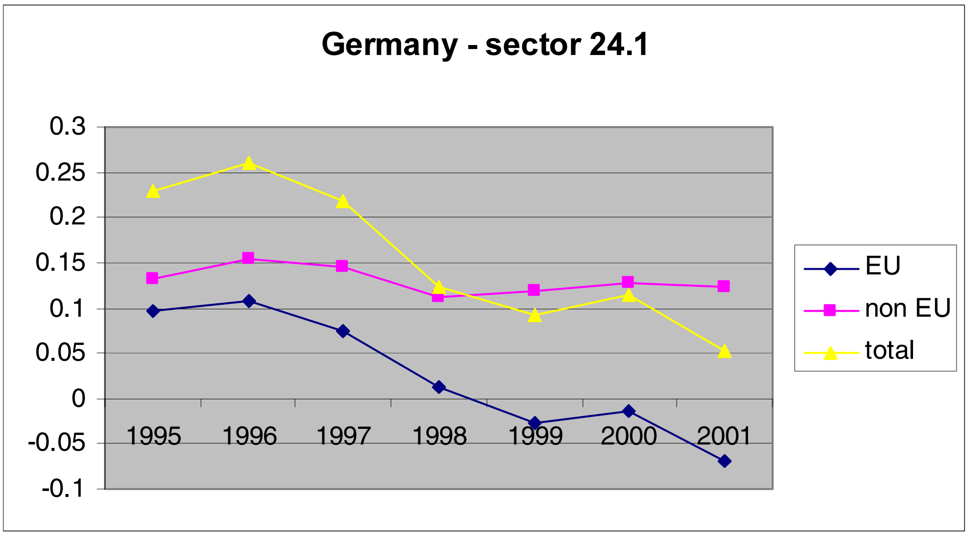


Source: COMETR database

The positive trend of net export in the German 'meat and meat product' sector is visible in both figures. The real output increased by around 16 percent and consumption by 4 percent. The increased competitiveness of this sector is reflected in an increase of 71 percent of export and a drop in imports by 10 percent.

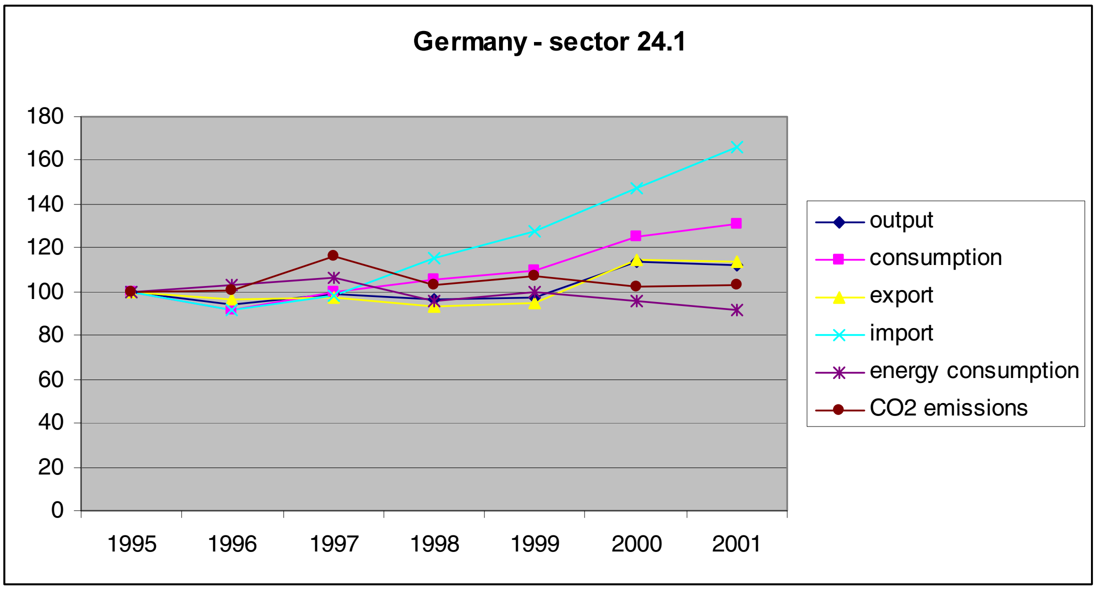
However, not all German sectors analysed in this report show the same trend. For example, the sector 24.1 ('basic chemicals') loses competitiveness based on the indicator net export, as presented in Figures 12 and 13.

Figure 12: Net export analysis of sector 24.1 ('basic chemicals' - Germany)



Source: COMETR database

Figure 13: Evolution of key variables of sector 24.1 ('basic chemicals' - Germany) – all monetary figures are presented in 1995 prices)



Source: COMETR database

An overview of the results of the net export analysis is shown in Table 6. A general trend is definitely not identifiable.

In a further step we determined the energy-intensity of the eight sectors applying the definition of energy-intensity of the 2003 Energy Taxation Directive of the European Union[19]. The directive defines an 'energy-intensive business' as an entity 'where either the purchases of energy products and electricity amount to at least 3,0 % of the production value or the national energy tax payable amounts to at least 0,5 % of the added value (Article 17 (1a))'. Total energy expenditure as well as the total tax burden has been calculated at the sectoral level in the COMETR database and the data illustrate that Sectors 24.1; 26.1; 26.5; 27.1-3; 27.4 must be described as 'energy-intensive' and the remaining three sectors (15.1; 21.2; 24.4) as 'non energy-intensive'.

[19] Council Directive 2003/96/EC - Restructuring the Community framework for the taxation of energy products and electricity.

Table 6: Results of the net export analysis[20]

	Net export decreasing – EU member states	Net export decreasing – non-EU member states	Net export decreasing – total trade	Net export increasing – EU member states	Net export increasing – non-EU member states	Net export increasing – total trade	No clear result or no data available
15.1 – non-energy int.	UK, SE	UK, SE	UK, SE	DE, DK	DE, DK	DE, DK	SI, FI, NL
21.2 – non-energy int.	UK, DK, SE, SI	UK, SE	UK, SE, SI	NL	DK, SI	DK, NL	DE, FI
24.1 – energy-intensive	DE	DE, NL, SI	DE, NL, SI	UK, DK, NL, SE	UK, SE, DK, SI	UK, SE, DK	FI
24.4 – non-energy int.	UK, FI, SI	NL	UK	DE, NL, SE	DE, FI, SE, SI	DE, NL, SE, SI	UK (non-EU), DK, FI (total trade)
26.1 – energy-intensive	SE, SI	UK, DK, SE, SI	UK, SE, SI	UK, DE	DE	DE	DK (eu, total trade)
26.5 – energy-intensive	UK, DK, SE, SI	UK, SI	UK, DK, SI	DE	DE, SE	DE, SE	DK (non-eu)
27.1-3 – energy-intensive	UK, NL, SI	UK, DK, NL	UK, NL, SI	DE, DK, FI	DE, FI, SE, SI	DE, FI, SE	DK (total trade), SE (eu)
27.4 – energy-intensive	UK,	NL, SE, SI	NL, SI	DE, NL, FI, SE, SI	UK, DE, FI	UK, DE, FI, SE	DK

Source: COMETR database

As mentioned above, this approach does not provide a complete answer concerning the competitiveness of a particular sector in a country nor does it give a comprehensive description of the PHH. Nevertheless it offers an indication of the trend of how domestic demand has been satisfied and how export and import has been evolving over time. First of all, it is interesting that there is no clear sign that energy-intensive sectors of these countries have lost competitiveness. However, the data show a declining trend of net exports for the majority of the UK sectors studied which is in strong contrast to the situation in Germany. It could therefore be argued – based on this analysis - that more UK sectors lost their comparative advantage than German sectors.

[20] See also the figures in Annex 3 – as mentioned in footnote 18 the really significant and meaningful results in terms of their interpretation are the ones with regard to total trade.

4. Pollution haven hypothesis in the context of trade-environment-development

An increasing body of academic literature exists in which the PHH is tested. Unsurprisingly, there are two different groups, either vehemently supporting the existence of the PHH or doubting its existence[21]. The empirical literature does not give a definitive answer as the methodologies applied differ widely. Another difficulty with regard to testing the hypothesis is the lack of appropriate data. Although some researchers confirm the existence of the PHH, the 'prevailing conclusion of the pollution haven literature is that environmental requirements have a small negligible effect on relocation' (Oikonomou et al., 2006, p.3663, see also Smarzynska and Wei, 2006). It may be further argued that the existence of the PHH, i.e. relocation of domestic industry takes place, can be interpreted as a loss of competitiveness of the domestic industry.

The reality clearly shows that relocation of industries from developed countries to developing countries and countries in transition takes place. But whether laxer environmental standards in receiving countries are a significant and decisive factor for this development must be questioned. Although studies also show that industries facing stricter environmental policies either in form of higher environmental costs or stricter environmental regulations relocate, the empirical evidence indicates that the strictness or laxity of environmental regulations is not determinative (Gray, 2002). What is more interesting as the driving factor for relocation, and one of the main driving forces for multinational companies in investing in foreign markets, is the increase in economic growth in developing countries (see for example: Smarzynska, 2003).

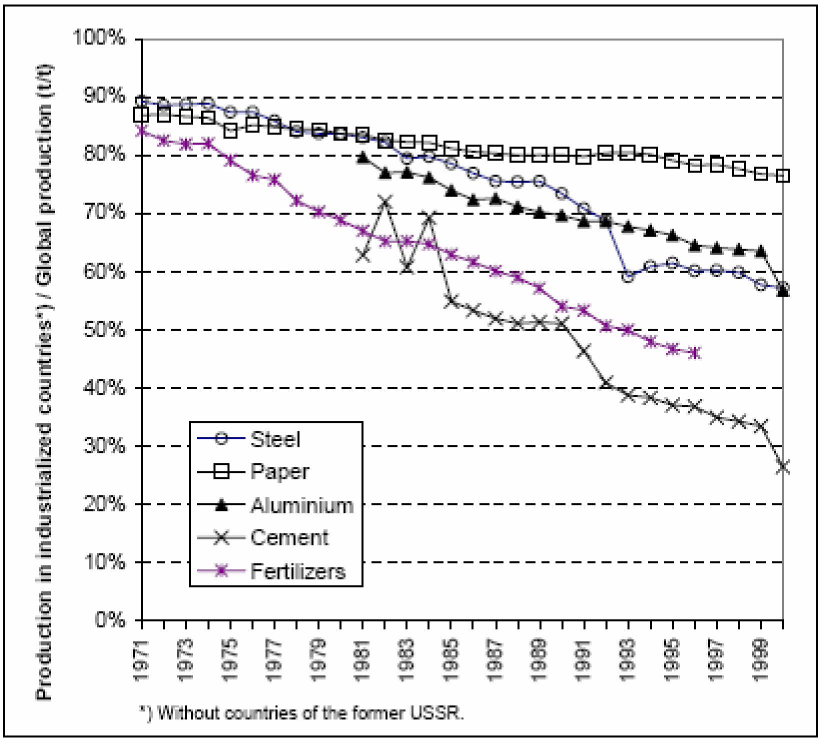
The starting point of our analysis was linked to the pollution haven hypothesis (PHH) and the question of whether stringent environmental policy leads to a relocation of industry. One of the major obstacles of assessing the PHH is the lack of appropriate variables measuring the stringency of environmental policy (see for example: Oikonomou et al., 2006, Dean et al., 2004 and work package 2 of COMETR, Fritz Gerald, Keeney and Scott, 2006). It is therefore rational to analyse whether the implementation of ETRs in the six EU member states, which can be assessed in terms of the stringency of environmental policy, led to some negative consequences with regard to the economic performance. The ETRs have been implemented in the countries studied either by increasing existing carbon-energy taxes or by introducing new carbon-energy taxes and electricity taxes as a policy approach to reduce energy consumption and simultaneously reduce CO2 emissions (see for a more detailed discussion: Speck, 2005).

The analysis of the PHH in relation to carbon leakage definitely has its merits, but it has to be stated that the whole discussion on carbon leakage as well as on the pollution haven hypothesis does not take account of some important topics.

Probably one of the most intriguing aspects is that the industrialised world has lost global market share in a whole range of different products, many of which must be described as energy-intensive products (see Figure 14). This development started already in the 1970s and proceeded in line with an increase in FDI in developing countries, in particular Asia, which accelerated even further during the 1990s. Changes in the availability of factors of production and the increase in demand for products and commodities in developing countries, in particular Asia, as a consequence of the globalisation process raised the interest of multinational companies in investing in developing countries. It is hard to imagine that stricter environmental policies in industrialised countries were the mechanism initiating the process of investing in developing countries, thereby triggering the relocation of industries. Despite the above, however, the majority of direct foreign direct investment still occurs between industrialised countries (UNCTAD, 2003).

Figure 14: Global production shares of energy-intensive products in industrialised countries (source: Sijm et al., 2004, p. 152)

[21] See for detailed discussion on PHH: Liddle, 2001; Cole, 2004; and Oikonomou et al., 2006.



These finding are confirmed when analysing developments in crude steel production as shown in Table 7[22]. The data presented in this table are expressed in relation to physical quantities. The last two columns of the table present the change of production in each country and total world production and the last column shows the changes in the national shares. The production of crude steel increased in five of the seven countries concerned between 1995 and 2004. The UK faced a severe drop in steel production and no data are available for Denmark in 2004. It is worth noting that the national share of world production fell in four countries but increased in Finland and Slovenia.

[22] See for a more detailed discussion and analysis of the iron and steel industry the case study on ferrous metals carried out by Christie et al., 2006 as part of the COMETR project.

Table 7: Production of crude steel and the national share of worldwide production of crude steel for selected countries (units: thousand metric tons and percent)

	1995		1998		2001		2004		% change 1995/2004	
	k tonnes	%	k tonnes	%	k tonnes	%	k tonnes	%	production	global share
DK	654	0.1	790	0.1	751	0.1	n.a.	n.a.		
FI	3,176	0.4	3,952	0.5	3,938	0.5	4,832	0.5	52.1	8.1
DE	42,051	5.6	44,046	5.7	44,803	5.3	46,374	4.4	10.3	-21.6
NL	6,409	0.9	6,377	0.8	6,037	0.7	6,848	0.7	6.9	-24.1
SE	4,953	0.7	5,153	0.7	5,518	0.7	5,978	0.6	20.7	-14.2
UK	17,604	2.3	17,315	2.2	13,543	1.6	13,766	1.3	-21.8	-44.4
SI	394	0.1	405	0.1	462	0.1	565	0.1	43.4	1.9
USA	95,191	12.7	98,658	12.7	90,104	10.6	99,681	9.4	4.7	-25.6
China	95,360	12.7	114,588	14.7	150,906	17.8	272,456	25.7	185.7	103.1
India	22,003	2.9	23,480	3.0	27,291	3.2	32,626	3.1	48.3	5.4
Russia	51,589	6.9	43,822	5.6	58,970	6.9	65,583	6.2	27.1	-9.7
World	752,271	100	777,320	100	850,338	100	105,8492	100	40.7	

Source: International Iron and Steel Institute, 2005 and authors' own calculation

A dramatic increase in crude steel production is noted in China where the growth in consumption between 1995 and 2004 is even higher (Table 8). This development is clearly reflected in the Chinese share of production and consumption in relation to global data.

Table 8: Apparent consumption of crude steel and national share of worldwide apparent consumption of crude steel in selected countries (units: thousand metric tons and percent)

	1995		1998		2001		2004		% change 1995/2004	
	k tonnes	%	k tonnes	%	k tonnes	%	k tonnes	%	consumption	global share
DK	2,099	0.3	2,267	0.3	1,956	0.2	2,012	0.2	-4.1	-34.3
FI	2,060	0.3	2,280	0.3	2,300	0.3	2,350	0.2	14.1	-21.8
DE	41,363	5.6	40,464	5.2	39,938	4.6	38,721	3.6	-6.4	-35.9
NL	5,550	0.7	6,070	0.8	4,980	0.6	4,380	0.4	-21.1	-45.9
SE	4,410	0.6	4,460	0.6	3,980	0.5	5,000	0.5	13.4	-22.3
UK	14,930	2.0	16,390	2.1	15,110	1.8	14,860	1.4	-0.5	-31.8
SI	767	0.1	873	0.1	1,115	0.1	1,249	0.1	62.8	11.6
USA	113,017	15.2	135,145	17.4	114,386	13.3	123,803	11.4	9.5	-24.9
China	101,100	13.6	122,939	15.8	170,648	19.8	302,200	27.9	198.9	104.8
India	26,080	3.5	27,100	3.5	31,200	3.6	38,300	3.5	46.9	0.6
Russia	25,582	3.4	21,085	2.7	34,740	4.0	37,176	3.4	45.3	-0.4
World	742,767	100	778,582	100	859,688	100	1,084,106	100	46.0	

Source: International Iron and Steel Institute, 2005 and authors' own calculation

The picture of the development of crude steel consumption in European countries is rather mixed as domestic consumption grew in Finland, Sweden and Slovenia but dropped in the other four EU countries. Interesting is the fact that there is no distinctive pattern in EU member states in the link between crude steel production and consumption. For example, Germany increased production by around 10 percent but consumption dropped by 6 percent during the period, meaning that an increasing share of German production was being exported. The complete opposite was the case in the UK where production dropped by a staggering 22 percent and consumption only by around 0.5 percent. The consequence was that the UK, once a net exporter of crude steel, became a net importer of crude steel to satisfy domestic demand.

Based on these data it can be concluded that crude steel production coped rather well with carbon-energy taxes implemented as part of ETR in the majority of the EU member states, as countries such as Finland, Germany and the Netherlands were able to increase net crude steel exports between 1995 and 2004. The clear contrast was the UK which saw a continuous drop in steel production. But this development started already before the climate change levy was introduced in 2001. It could be argued that EU member states faced a decline in competitiveness as national shares of world production held by EU member states dropped during this period. However, this argumentation opposes the reality of globalisation, as developing countries are getting richer and investing in their own production capacity.

One of the underlying assumptions of the pollution haven hypothesis is an increase in foreign direct investment (FDI) as the source of establishment of new production capacities in foreign countries, in particular in relation to relocation of industries to developing countries. However, it is rather surprising that studies analysing the existence of the PHH do not account for the underlying reasons and determinants of FDI, i.e. the reasons why multinational companies invest in foreign countries. This question is regularly suppressed; although the trade literature does offer some plausible arguments for FDI. The literature distinguishes between different types of FDI – probably the most significant types are (see, for example, Christie, 2003 and Demeskas et al., 2005):

- Horizontal FDI (market-seeking investment): FDI is undertaken with the aim of satisfying demand of the market in which investment is made (i.e. foreign market from the perspective of the investor).
- Vertical FDI (cost-minimizing investment or efficiency-seeking investment): a multinational company invests in a foreign country as the costs are lower so that the production costs are minimised.

FDI is quite significant in any analysis of the PHH, as relocation of industries requires the establishment of production capacity in foreign countries. It may be argued that investments according to the horizontal FDI type is of limited significance with regard to the PHH as the main motivation is produce for the national markets and not for export. This contrasts with vertical FDI of multinational companies, as this type of investment aims to produce at lowest cost and to sell the products globally. However, this differentiation with regard to the motivation for FDI is not part of the analysis of PHH; although it may be argued that studies analysing FDI in the context of carbon leakage and the pollution haven hypothesis are often based on the vertical FDI assumption (reason for investment decision is to reduce costs, i.e. an argument / motivation of cost-efficiency), and thereby do not take into account that the investment decision may be part of the globalisation process by building up production capacity in foreign countries – developing countries and economies in transition – with the aim of satisfying the increased demand of these countries.

Furthermore, developed / industrialised countries are shifting away from industry-dominated economies (in particular heavy industries, such as iron and steel, as is obviously the case in the UK as indicated in Tables 7 and 8) towards service-orientated economies, meaning that the importance of the manufacturing industry (as expressed in relation to its share of GDP) is diminishing over time.

However, multinational enterprises face the question of where to invest, i.e. the choice of location. A large number of studies analysing FDI and its determinants exist. Host countries can benefit from FDI in the sense that knowledge and technology are transferred to domestic firms, and an increase in the labour force and productivity spillovers can be expected. Nevertheless, FDI may also lead to some unwanted results, as large multinational enterprises may be able to misuse their dominant position, in particular in small economies, to negotiate very preferable conditions and concessions minimising their tax obligations (Demeskas et al., 2005).

When analysing the empirical literature on FDI it becomes evident that gravity factors, such as host market size as well as geographical and cultural proximity between source and host country, represent key reasons for explaining FDI flows. Apart from these factors the policy environment in the host country is also important, namely that high unit labour costs, high corporate tax burden and import tariffs discourage FDI, as opposed to liberal foreign exchange and trade regimes and advanced reforms in the infrastructure sector which promote FDI (Demeskas et al., 2005, p.24).

As this research is directed at the question of whether energy taxation as part of an environmental fiscal reform process may lead to the relocation of domestic industries, it is interesting to assess whether the empirical literature on FDI studies whether energy taxation is a cause of FDI, i.e. for the relocation of domestic industries. Environmental policy issues, in particular energy taxation, are topics which are normally not included as determining factors in FDI studies. This is also reflected in the different competitiveness indicators developed by institutions, such as the World Bank and the World Economic Forum, as these ranking exercises are seen as a tool for assessing the attractiveness of undertaking investment (Oikonomou et al., 2006).

Empirical studies linking FDI and environmental policies are rare and the oft- mentioned argument is that foreign firms interested in investing in foreign countries are more concerned with having consistent environmental regulation affecting all possible competitors rather than lax environmental policy (Aliyu, 2005).

However, a recent study is very interesting in this context as it includes environmental taxes/levies in the assessment of FDI and PHH in China (Dean et al., 2004). The authors summarise their findings as: 'Environmental stringency does affect location choice, but not in the manner described by the pollution haven hypothesis. Relatively weak environmental levies are a significant attraction for joint ventures with partners from Hong Kong, Macao, Taiwan, and other Southeast Asian developing countries. In contrast, joint ventures with partners from industrial country sources (e.g., US, UK and Japan) are actually attracted by stringent environmental levies, regardless of the pollution intensity of the industry.' (Dean et al., 2004, p.ii)

They elaborate their results even further: 'Conditional logit analysis provides some evidence that Chinese-sourced FDI is deterred by relatively stringent pollution regulation, particular in highly polluting industries. This supports the pollution haven hypothesis. However, FDI from non-Chinese sources is actually attracted to provinces with more stringent environmental regulations, regardless of pollution-intensity--the opposite of the pollution haven hypothesis. Our results suggest the importance of accounting for firm heterogeneity in considering the attraction of weak environmental regulations. Firms in industries that use low-polluting processes are unlikely to be responsive to pollution taxes. Firms in heavily polluting processes, however, can be expected to respond to the implied factor-price difference. We have shown, however, that industry heterogeneity is not the full story. Our evidence is consistent with the view that important international differences in production processes and pollution-control technology exist. While we have no direct measure of technological sophistication, the contrasting results we find for Chinese-sourced and non-Chinese-sourced investment, coupled with other evidence on the extent of technology transfer, suggest that technology mediates the link between low standards and firm location decisions.' (Dean et al., 2004, pp.23, 24)

This result is in itself remarkable as it clearly indicates that environmental taxes are of less concern with regard to investment decisions for companies from developed countries as opposed to countries with less stringent environmental policies. In this context the finding of a recent study is also interesting as it spells out that the participation in international environmental treaties may be a factor determining the attractiveness of FDI: 'there is some evidence that investment from pollution-intensive multinational firms as a share of total inward FDI is smaller for host countries with a higher environmental standards. However, these findings do not survive various extensions and robustness checks.' (Smarzynska and Wei, 2001, p.5)

One of the causes of the paucity of studies analysing environmental taxes and trade may be linked to the current carbon-energy tax schemes which either completely exempt or at least heavily reduce industries from the often rather high nominal tax burden. An OECD report concluded therefore: 'In fact, most existing environmental taxes seem to be too low to induce discernible trade impacts. Simulation studies often concern hypothetical high carbon energy taxes, currently not in existence (OECD, 1996, p.77)'.

This finding must be taken into account when assessing the results of studies analysing the effects of carbon- energy taxes and the consequences of these taxes on trade and carbon leakage. Oikonomou and colleagues compare the results of three models analysing the introduction of a carbon tax in the iron and steel sector (Oikonomou et al., 2006) and find out that a stricter policy expressed as the implementation of a CO2 tax in developed countries, i.e. the so-called Annex I countries under the Kyoto Protocol, leads to higher carbon leakage rates. However, the leakage rates, and the production and trade of iron and steel products respectively, differ between the models substantially, so that the authors conclude: 'this diversity of results seems to indicate that the results are subject to major uncertainties.' (Oikonomou et al., 2006, p.65)

5. Summary and conclusion

Although this report does not provide verifiable and final answers to questions analysing the pollution haven hypothesis and the carbon leakage hypothesis it offers some interesting insights with regard, in particular, to the decoupling analysis undertaken in section 2 of this paper. This part of the report indicates a rather heterogeneous picture as the results are very mixed: absolute decoupling can be found in some sectors in some EU member states but during the same time period inverse decoupling of the same sector occurred in other EU member states. The causes for this disparate evolution have not been identified as the approach applied cannot be used for this purpose.

The findings of the net export analysis as a tool for assessing the pollution haven hypothesis are also multi-faceted and diverse as the data indicate that domestic consumption in some of the EU member states analysed has to be increasingly met via imports as compared to the situation where an increasing part of domestic consumption has been satisfied via domestic production during the time period studied. A coherent picture cannot be drawn – neither for the economic sectors nor for the countries. This finding may be interpreted as that several countries have even increased their competitive advantage in specific sectors compared to the rest of the world during a period where all those countries analysed in Section 3.2 have implemented some kind of tax shifting programme by increasing energy-related taxes and reducing other taxes.

The evolution of the performance of the iron and steel sector (NACE classification 27.1-3) is one of the more interesting results. During the period between 1995 and early 2000 in the seven EU member states production and consumption, measured in real terms, fall. The only exception is Finland which slightly increased the output of this sector. However, countries, such as Finland, Germany, and Sweden, increased the export volume. An analysis based on the figures presenting the physical quantities of crude steel produced and consumed shows a slightly different picture as these data indicate an increase in crude steel production in five of the seven EU member states (Finland, Germany, Netherlands, Slovenia and Sweden) and a major fall in the UK. The increase in production in Germany and the Netherlands is not accompanied by an increase in apparent consumption in these two countries. This led to an increase in the net export figures which means that the competitive advantage has not been reduced. The situation was different in Finland and Sweden as the increase in production was accompanied by an increase in domestic consumption. The situation in the UK and in Denmark was completely different as there is almost no change in crude steel production between 1995 and 2004 reported but a big fall in consumption. This recent development of the crude steel industry in EU member states occurred during a time period in which world crude steel production and consumption increased dramatically and therefore it is not surprising that the domestic share of global production and worldwide consumption dropped.

When examining the PHH attention should also be directed to the topic of FDI as the timely establishment of production capacity is a prerequisite for relocation of industries. This is valid for all causes which can represent the underlying reasons for relocation of industries. The empirical literature indicates that gravity factors, such as company taxation and the skill of the labour force, are decisive determinants for FDI and that environmental policy issues have a very low significance for location decisions made by multinational companies.

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Annex 1: Leakage analysis within a decoupling framework

This technical note provides an analytic framework for linking the concepts of decoupling, competitiveness (as measured by the net export ratio) and carbon leakage.

1. Decoupling

Unit environmental pressure (UEP) can be measured with respect to emissions (i.e. ω_Z), or with respect to energy (ω_E). The relationship between the two is given by:

$$\omega_Z = \frac{Z}{C} = \frac{Z}{E} \times \frac{E}{C} = \zeta \times \omega_E \qquad \ldots (1)$$

where

Z = Emissions (tCO_2)

E = Energy use (joules)

C = Consumption (Euro-constant)

ζ = emissions factor (tCO_2 / joule)

The decoupling factor (DF) with respect to emissions is defined as the percentage change in ω_Z (NB: this is exactly equivalent to the definition in Box 1):

$$\delta_Z = \frac{\omega_Z^0 - \omega_Z^1}{\omega_Z^0}$$

The decoupling factor is commonly calculated over time – i.e. the change between two time periods. However, it can also be calculated over different states of the world – for example, the change between a world without a particular policy intervention and the world with that intervention. It is this second interpretation that is assumed in developing the framework.[23]

For small changes, the decoupling factor can be defined in terms of the differential:[24]

$$\delta_Z = \frac{d\,\omega_Z}{\omega_Z} = \frac{d\zeta}{\zeta} + \frac{dE}{E} - \frac{dC}{C}$$

$$= \frac{d\zeta}{\zeta} + \delta_E \qquad \ldots (2)$$

The decoupling factor with respect to emissions is equal to the percentage change in the average emissions factor plus the decupling factor with respect to energy; where the latter is equal to the difference between the percentage change in energy use and the percentage change in consumption.

2. Competitiveness

The net export ratio (η) of a country is defined as:

$$\eta = \frac{X - M}{C} = \frac{Y - C}{C} = \frac{Y}{C} - 1 \qquad \ldots (3)$$

[23] The practical implications of this assumption for the empirical analysis are discussed in the conclusion.

[24] For non-marginal changes, the expressions should also include cross-product terms. For example, there is an addition term $(d\zeta/\zeta)\times\delta_E$. However, in practice these second-order terms are not likely to be significant.

where

X	=	Exports
M	=	Imports
Y	=	Output

Under this definition, consumption includes investment expenditure (in fixed capital and stocks) as well as final consumption.

By definition, global production ($\hat{Y}$) must be equal to global consumption ($\hat{C}$). Put another way, global exports must be equal to global imports. Therefore:

$$\eta = \frac{\sigma}{\rho} - 1 \qquad \ldots (4)$$

where

σ	=	share of global production (i.e. $Y / \hat{Y}$)
ρ	=	share of global production (i.e. $C / \hat{C}$)

Thus, the net export ratio is equal to the ratio of the country's share of global production to its share of global consumption, minus one. A necessary and sufficient condition for the net export ratio (η) to fall is that:

$$\frac{d\sigma}{\sigma} < \frac{d\rho}{\rho} \qquad \ldots (5)$$

Thus, the net export ratio will fall if the country's share of global production grows more slowly (declines more quickly) than its share of global consumption. Conversely, it will rise if its share of global production grows more quickly (declines more slowly) than its consumption share.

The definition of the net export ratio in terms of the country's shares of global production and global consumption (4) suggests that it might provide a good competitiveness indicator, with movements in the ratio giving an indication of changes in competitiveness – i.e. a declining ratio indicating a deterioration in competitiveness, an increasing ratio indicating an improvement.

It is the potential of the net export ratio to provide an indicator of changes in competitiveness that make it a useful variable to analyse, together with the fact that it can provide a link between decoupling and carbon leakage (see Sections 3 and 5 below of this annex). It does not necessarily provide an indication of the extent to which domestic demand is satisfied by an increase in imports. This is provided by the import intensity (i.e. M / C) and it is quite possible for the net export ratio to decline while import intensity rises, and vice versa. Also, it does not necessarily follow that a declining net export ratio implies that relocation of production has occurred[25] – let alone that the pollution haven hypothesis is valid!

The overall net export ratio is arithmetically equal to the weighted average of the component ratios for different global regions (e.g. EU15 and the rest of the world), where the weights are equal to the proportions of total consumption that are produced in the respective regions.

$$\eta = \sum \left(\frac{C_i}{C}\right)\eta_i \qquad \eta_i = \frac{X_i - M_i}{C_i}$$

where

X_i	=	Exports to region *i*
M_i	=	Imports from region *i*
C_i	=	Consumption of goods consumed in region *i*

[25] Relocation of production by firms in the regulated country does not necessarily require relocation of capacity (i.e. foreign direct investment). It may occur via changes in the utilization of the firms' existing capacity in different countries.

Note: The individual ratios should be calculated using the consumption of goods produced within the respective regions (in the case of two regions, $C_1 = C - M_2$ and $C_2 = C - C_1$).

However, unless net exports between regions are all equal to zero, the individual net export ratios cannot be interpreted in terms of the ratio of the country's share of total region production to its share of total region consumption (i.e. σ_i / ρ_i). Consequently, in general it is not clear that movements in the individual ratios provide any indication of changes in competitiveness relative to other countries in the region.

3. Relationship between decoupling and competitiveness

Together, conditions (1) and (4) imply that:

$$\omega_Z = \zeta \times \frac{E}{Y} \times \frac{Y}{C}$$

$$= \zeta \times \varepsilon \times (1 + \eta) = \zeta \times \varepsilon \times \gamma \qquad (6)$$

where

ε = energy intensity (joules per Euro-constant)

γ = production – consumption ratio (i.e. Y / C, or σ / ρ)

It follows directly that

$$\delta_Z = \frac{d\,\omega_Z}{\omega_Z} = \frac{d\zeta}{\zeta} + \frac{d\varepsilon}{\varepsilon} + \frac{d\gamma}{\gamma} \qquad (7)$$

Thus, the decoupling factor with respect to emissions is determined by three things: the percentage change in the emissions factor; the percentage change in the energy intensity of the sector; and the percentage change in the production-consumption ratio for the sector.

Condition (7) has a number of implications. In particular:

- If the emissions factor and / or energy intensity decline, then it is possible for decoupling to be accompanied by increasing competitiveness – i.e. there need not be a trade-of between the two.[26]
- If there is no change in either the emissions factor or energy intensity, then decoupling can only be achieved at the expense of a loss in competitiveness.

Of course, one would expect the policy intervention (i.e. the regulation or tax) to cause a reduction in the emissions factor or energy intensity, or both. In which case, it is possible for decoupling to be accompanied by increasing competitiveness.

4. Carbon leakage

Global carbon emissions are equal to global output multiplied by the global average emissions intensity; where the latter is equal to the weighted average of the emissions intensity in the regulated country and the intensity in the rest of the world, i.e.

$$Z^G = [\,\sigma\,\zeta\,\varepsilon + (1-\sigma)\,\zeta^R\,\varepsilon^R\,]\ \hat{Y} \qquad (8)$$

where

ζ^R = average emissions factor for rest of world (ROW)

[26] There is a direct relationship between the production-consumption ratio and the net export ratio. When one increases (decreases), so does the other.

ε^R = average energy intensity for rest of world (ROW)

The total differential of (8) is:

$$dZ^G = [\, \zeta\, \varepsilon\, (\sigma\, d\hat{Y} + d\sigma\, \hat{Y}) + (\varepsilon\, d\zeta + \zeta\, d\varepsilon)\, \sigma\, \hat{Y} \,] + [\, \zeta^R \varepsilon^R (1-\sigma)\, d\hat{Y} - \zeta^R \varepsilon^R\, d\sigma\, \hat{Y} + (\varepsilon\, d\zeta^R + \zeta\, d\varepsilon^R)(1-\sigma)\, \hat{Y} \,]$$

The expression inside the first set of square brackets relates to the change in own-country emissions, while the expression inside the second set of square brackets represents the change in emissions in the rest of the world.

For a given policy initiative (e.g. a regulation, an emissions tax, etc.), the sign of the own-country impact would be expected to negative (i.e. own country emissions are reduced – all else being equal). However, the impact on the rest of world emissions can be positive or negative, depending the signs and magnitudes of the individual components. A necessary and sufficient condition for positive carbon leakage (i.e. for rest of world emissions to rise) is that:

$$\frac{d\sigma}{\sigma} < \frac{(1-\sigma)}{\sigma}\left[\frac{d\hat{Y}}{\hat{Y}} + \frac{d\varepsilon^R}{\varepsilon^R} + \frac{d\zeta^R}{\zeta^R}\right] \quad \ldots \quad (9a)$$

or

$$\frac{d(1-\sigma)}{1-\sigma} > -\left[\frac{d\hat{Y}}{\hat{Y}} + \frac{d\varepsilon^R}{\varepsilon^R} + \frac{d\zeta^R}{\zeta^R}\right] \quad (9b)$$

That is, the percentage increase in the rest of world market share must be greater than a threshold value; which depends on the magnitudes and signs of the impacts of the policy intervention on global production and the average emission factor and energy intensity for rest of world producers.

5. Relationship between carbon leakage and competitiveness

Under the assumption that the policy intervention in the regulated country does not affect consumption in any other country (which seems reasonable), then $d\hat{Y} = d\hat{C} = dC$ and it follows that:

$$\frac{d\hat{Y}}{\hat{Y}} = \frac{dC}{C}\rho = \left(\frac{\rho}{1-\rho}\right)\frac{d\rho}{\rho}$$

Therefore condition (9a) can be restated as:

$$\frac{d\sigma}{\sigma} < \frac{d\rho}{\rho} + \frac{1}{\sigma}\left[\left(\frac{\rho-\sigma}{1-\rho}\right)\frac{d\rho}{\rho} + (1-\sigma)\left(\frac{d\varepsilon^R}{\varepsilon^R} + \frac{d\zeta^R}{\zeta^R}\right)\right] \quad (10)$$

Assuming that the policy intervention does not give rise to an increase in consumption in the regulated country (i.e. $dC \leq 0$ and hence $d\rho \leq 0$), the sign of the expression inside the square brackets depends on the relative values of ρ and σ, and the impact of the intervention on the average emission factor and energy intensity for the rest of the world.

If the impact on the rest of the world is negligible (as seems likely to be the case), the expression inside the square brackets is positive if $\sigma > \rho$, and it is negative if $\sigma < \rho$.

If $\underline{\sigma > \rho}$ (i.e. the net export ratio is greater than zero), then condition (10) is guaranteed to be satisfied whenever condition (5) is satisfied. That is, a <u>declining net export ratio implies that carbon leakage is positive</u>. Similarly, condition (5) is guaranteed not to be satisfied when condition (10) is not satisfied. That is, the negative carbon leakage implies that the net export ratio is rising. However, it does <u>not</u> necessarily follow that a rising net export ratio implies that carbon leakage is negative.

If $\rho > \sigma$ (i.e. the net export ratio is less than zero), then the opposite is true. A rising net export ratio implies that carbon leakage is negative; while positive carbon leakage implies that the net export ratio is falling. However, again it does not necessarily follow that that a declining net export ratio implies that carbon leakage is positive.

6. Conclusions

If decoupling is defined relative to consumption then there is a clear relationship between the value of the decoupling factor with respect to emissions and changes in the average emission factor, energy intensity and net export ratio (condition (7)). To the extent that changes in the net export ratio indicate changes in competitiveness, this can be used to assess the relationship between decoupling and competitiveness. In particular, if the average emissions factor and / or average energy intensity are declining, then it is possible to have both decoupling and improvements in competitiveness. However, if neither is declining then it is only possible to have decoupling at the expense of competitiveness.

This relationship is valid both for changes between different states of the world (e.g. without and with regulation) and for changes over time. However, while changes between states of the world can be attributed directly to specific policy interventions, this is not generally possible for changes over time, which may be driven by a range of different factors.

The relationship between changes in the net export ratio (and hence competitiveness) and carbon leakage are more complex. Furthermore, the relationship is based on the assumption that the policy intervention is the only factor affecting the outcome. Consequently, the relationship is unlikely to be valid for changes over time, where other factors are also likely to have affected global emissions and output. In practice however this is not a significant issue as there is no information on actual carbon leakage – and hence it is not possible to perform any empirical analysis of the relationship. All that we can do is conduct a "thought experiment"; comparing the actual outcome in a given year with a counterfactual outcome in which the policy intervention is omitted, but all other factors remain the same.

For changes between different states of the world, the relationship between changes in the net export ratio and carbon leakage depends on the value of the ratio. If the ratio is positive (i.e. the country's share of global production is greater than its share of consumption), then a reduction implies that there is positive carbon leakage; while if the ratio is negative, then an increase implies that there is negative carbon leakage. For the other two cases (e.g. an increasing positive ratio, etc.), it is not possible to draw unambiguous conclusions about carbon leakage – it may be positive or negative.

Thus, the net export ratio can provide an indicator both for changes in competitiveness and (in some circumstances) for the sign of any carbon leakage. In particular, if a policy intervention causes the net export ratio of a particular sector to decline, there will be both a loss of competitiveness and positive carbon leakage if the value of ratio is positive. If the value of the ratio is negative, then while there will still be a loss of competitiveness, it is possible that carbon leakage may be negative.

Annex 2: Detailed results of the decoupling analysis regarding the eight NACE 3 sectors in seven EU member states

As mentioned above decoupling indicators represent an approach which offers a clear picture of whether or not decoupling occurred. However, it does not differentiate according to whether *absolute* or *relative* decoupling takes place. The tables below presenting the results of the decoupling trends in all sectors and countries thereby distinguishing between *absolute, relative* and *inverse* decoupling. The definition of the three different types of decoupling are defined as follows:

Absolute decoupling*:*

- growth rate of economic variable is positive and growth rate of environmental variable is stable or negative

Relative decoupling*:*

- growth of environmental variable is positive but less than the growth rate of the economic variable
- growth rates of environmental and economic variables are both negative but the decline in the economic variable is greater than the change in the environmental variable

Inverse decoupling:

- growth rate of economic variable is negative and growth rate of environmental variable is positive
- growth rates of environmental and economic variables are both positive and the increase in the environmental variable is greater than the change in economic variable
- growth rates of environmental and economic variables are both negative and the decline in the economic variable is greater than the change in environmental variable

Table A.1.1: Decoupling analysis sector 15.1: meat and meat products

	Energy - output (1995 prices)	**Energy - consumption (1995 prices)**
UK	absolute	absolute
DE	absolute	absolute
DK	relative	inverse
NL	inverse	inverse
FI	inverse	n.a.
SE	absolute	absolute
SI	inverse	inverse

Source: author's own calculation based on COMETR database – work package 3

Table A.2.2: Decoupling analysis sector 21.2: paper and paper products

	Energy - output (1995 prices)	Energy - consumption (1995 prices)
UK	relative	relative
DE	absolute	absolute
DK	inverse	inverse
NL	inverse	inverse
FI	relative	n.a.
SE	inverse	inverse
SI	inverse	inverse

Source: author's own calculation based on COMETR database – work package 3

Table A.1.3: Decoupling analysis sector 24.1: basic chemicals

	Energy - output (1995 prices)	Energy - consumption (1995 prices)
UK	inverse	inverse
DE	absolute	absolute
DK	relative	inverse
NL	inverse	relative
FI	relative	n.a.
SE	inverse	inverse
SI	inverse	inverse

Source: author's own calculation based on COMETR database – work package 3

Table A.1.4: Decoupling analysis sector 24.4: pharmaceuticals

	Energy - output (1995 prices)	Energy - consumption (1995 prices)
UK	relative	relative
DE	relative	relative
DK	relative	relative
NL	absolute	absolute
FI	absolute	absolute
SE	relative	relative
SI	inverse	inverse

Source: author's own calculation based on COMETR database – work package 3

Table A.1.5: Decoupling analysis sector 26.1: cement, lime and plaster

	Energy - output (1995 prices)	Energy - consumption (1995 prices)
UK	absolute	absolute
DE	relative	inverse
DK	inverse	inverse
NL	inverse	n.a.
FI	relative	n.a.
SE	absolute	absolute
SI	relative	absolute

Source: author's own calculation based on COMETR database – work package 3

Table A.1.6: Decoupling analysis sector 26.5: glass and glass products

	Energy - output (1995 prices)	Energy - consumption (1995 prices)
UK	absolute	absolute
DE	inverse	inverse
DK	absolute	absolute
NL	relative	n.a.
FI	n.a.	n.a.
SE	inverse	inverse
SI	inverse	inverse

Source: author's own calculation based on COMETR database – work package 3

Table A.1.7: Decoupling analysis sector 27.1-3: ferrous metals

	Energy - output (1995 prices)	Energy - consumption (1995 prices)
UK	inverse	inverse
DE	inverse	inverse
DK	inverse	inverse
NL	relative	inverse
FI	inverse	inverse
SE	inverse	inverse
SI	inverse	inverse

Source: author's own calculation based on COMETR database – work package 3

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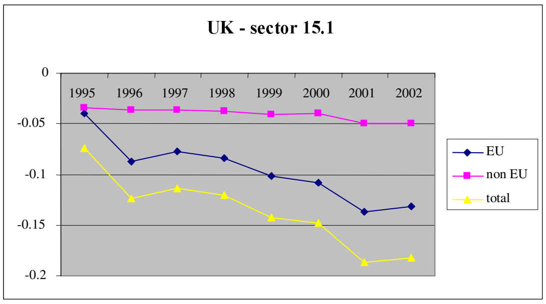
able A.1.8: Decoupling analysis sector 27.4: non-ferrous metals

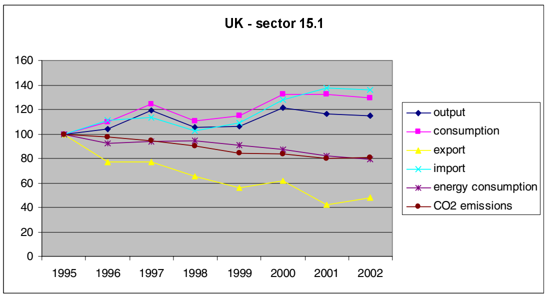
	Energy - output (1995 prices)	Energy - consumption (1995 prices)
UK	inverse	inverse
DE	relative	inverse
DK	absolute	absolute
NL	inverse	relative
FI	inverse	inverse
SE	inverse	inverse
SI	inverse	inverse

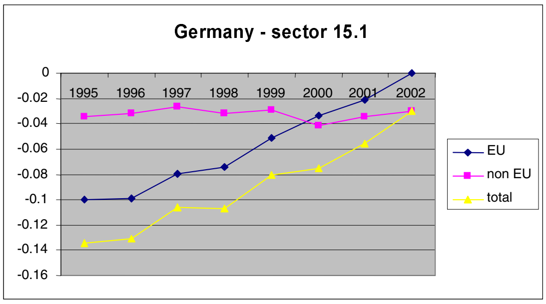
Source: author's own calculation based on COMETR database – work package 3

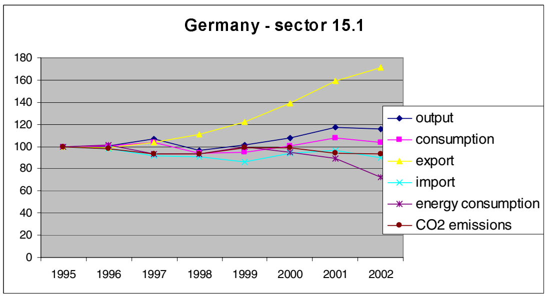
Annex 3: Detailed graphs on net export analysis and the evolution of key variablesof the individual sectors

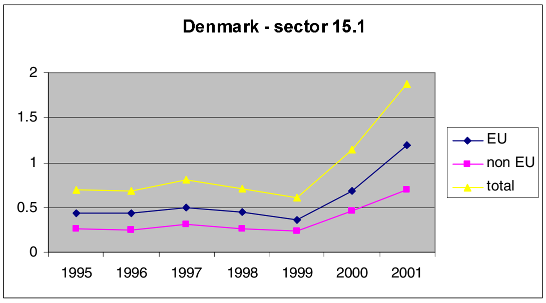
Sector 15.1: Meat and meat products

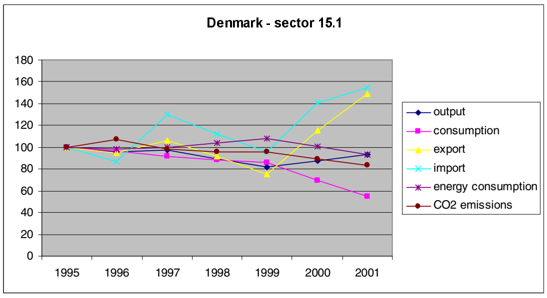


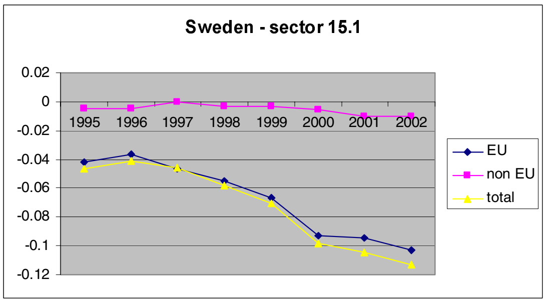


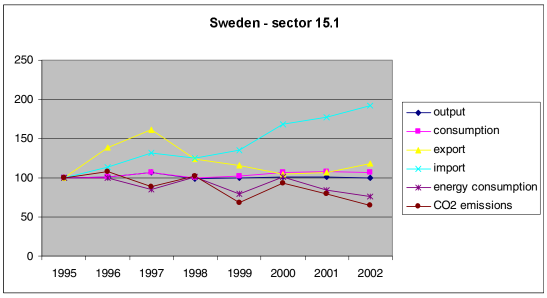


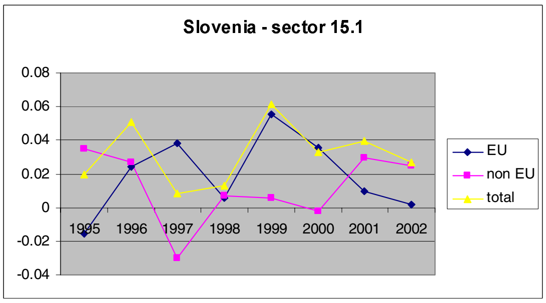


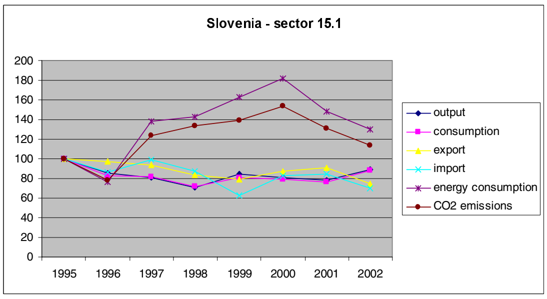




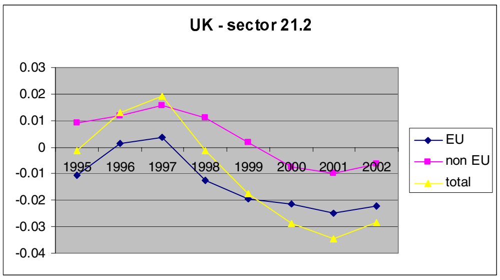


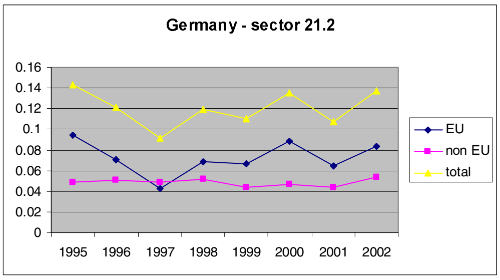


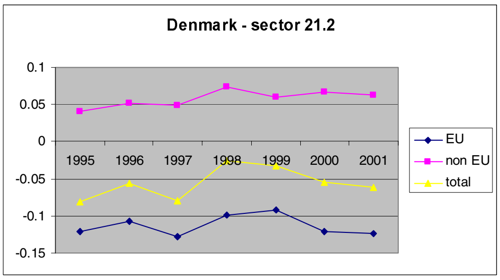


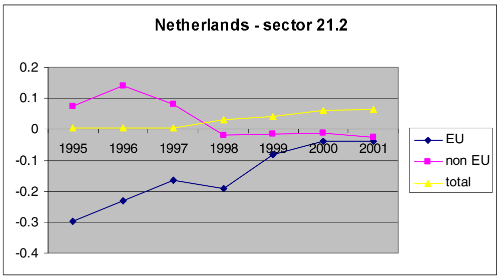


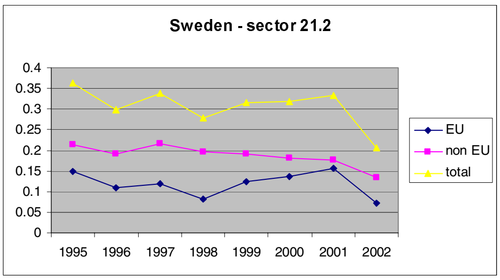
Sector 21.1: Paper and paper products

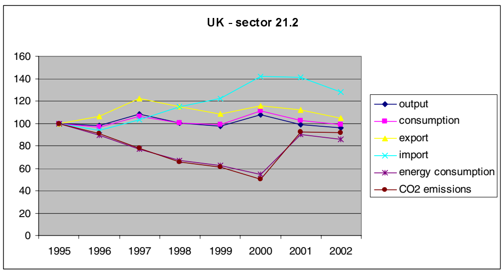


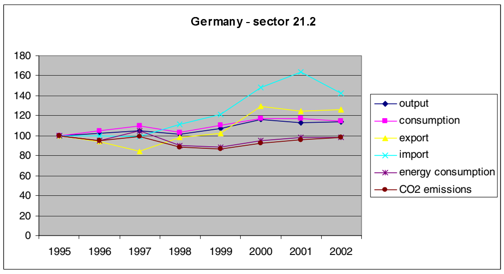


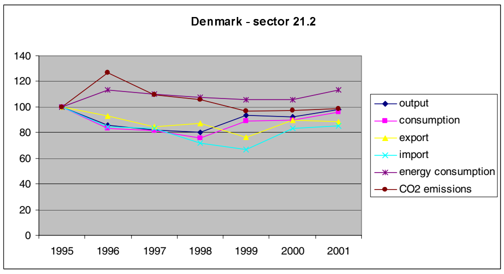


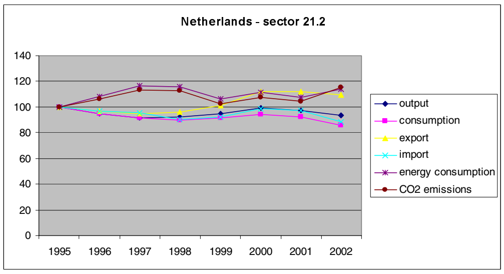


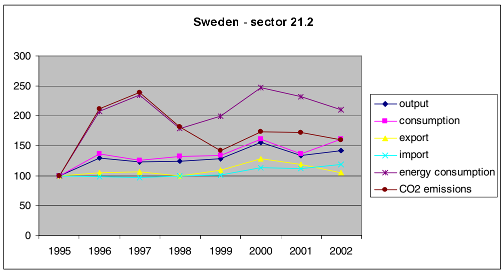


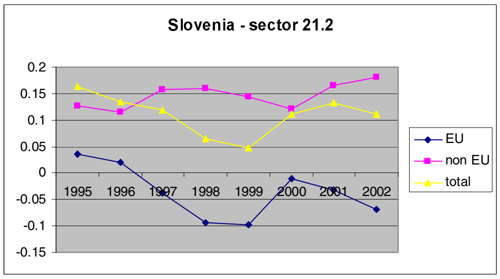


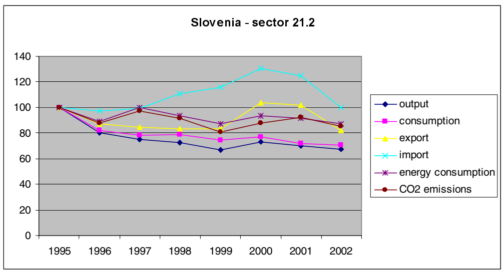




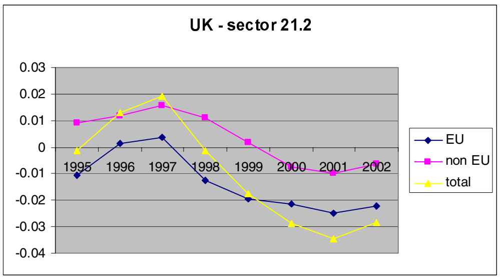


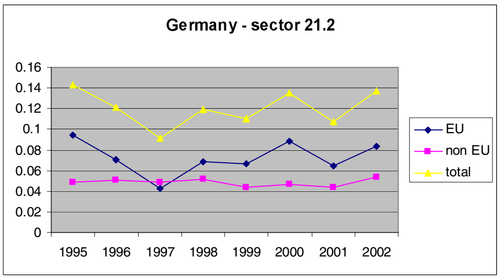


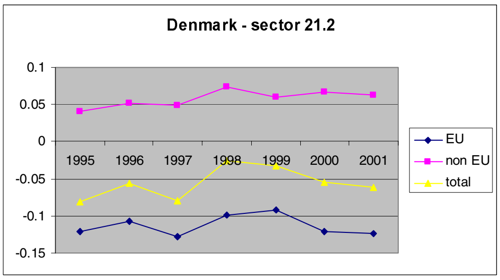


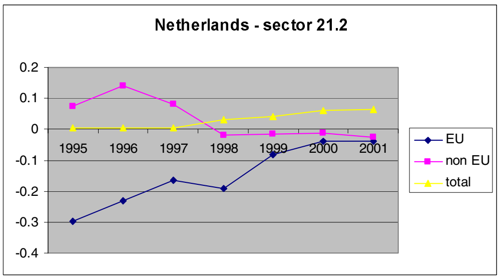


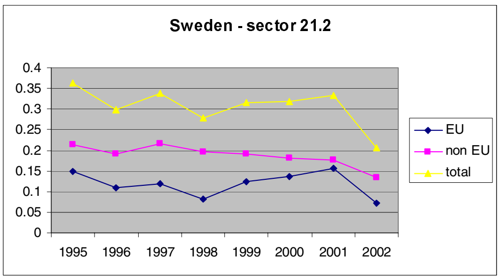
Sector 24.1: Basic chemicals

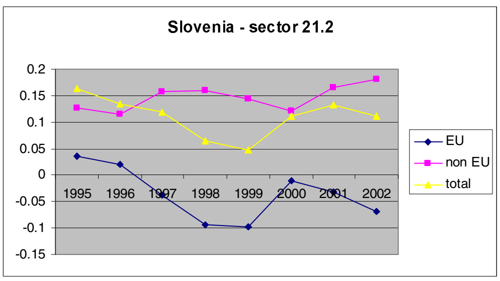


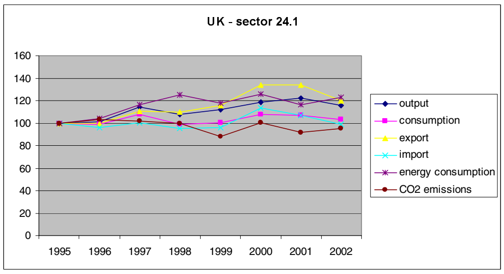


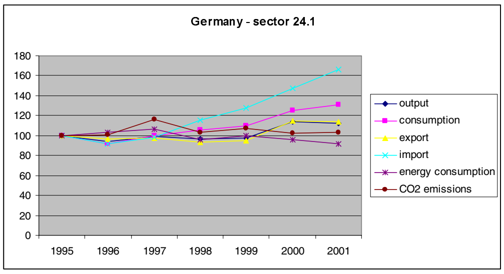


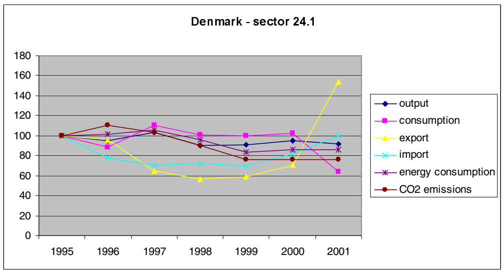


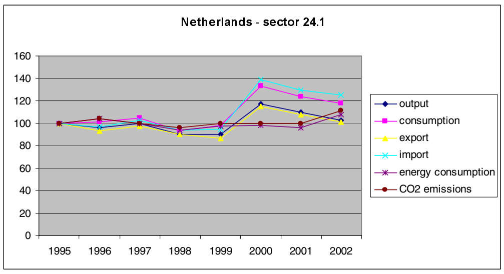


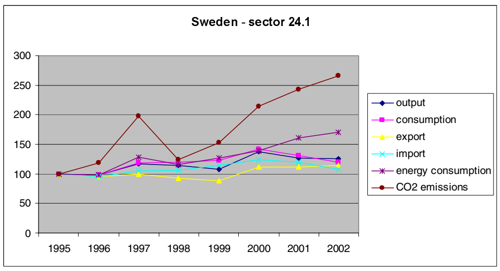


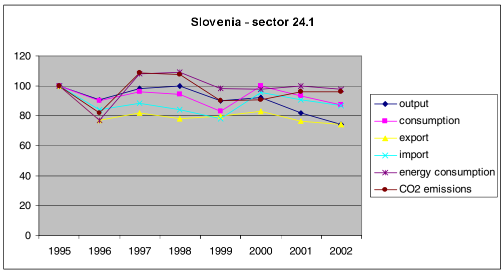




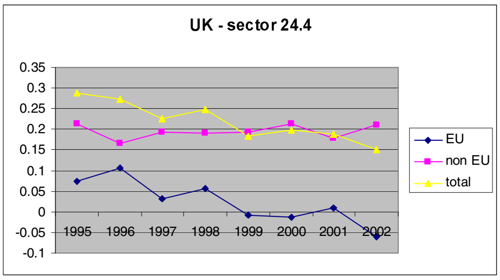


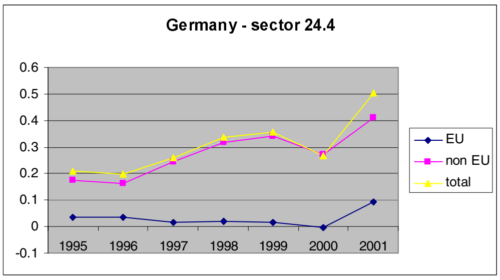


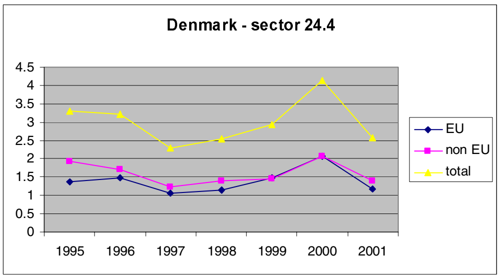


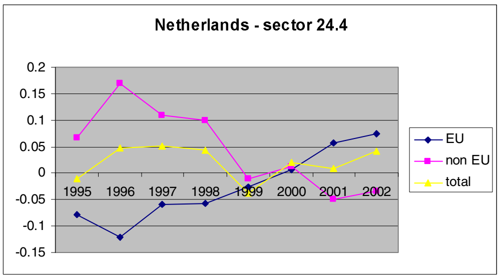


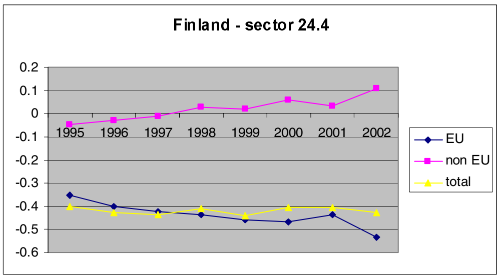
Sector 24.4: Pharmaceuticals

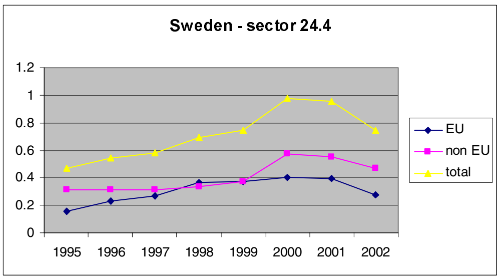


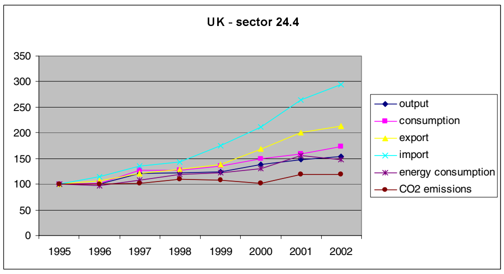


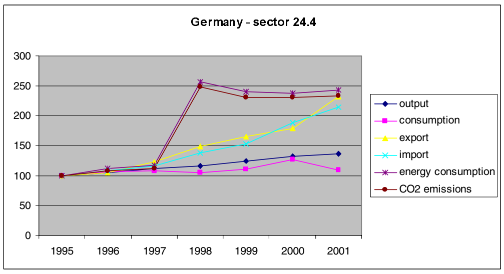


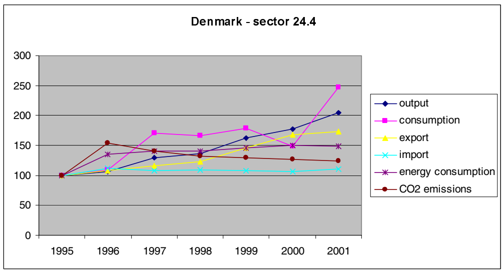


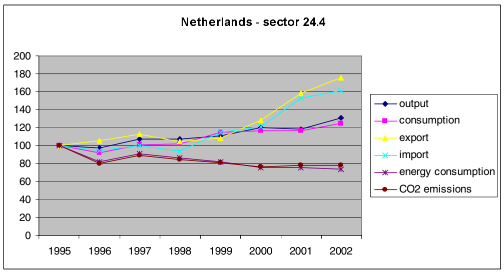


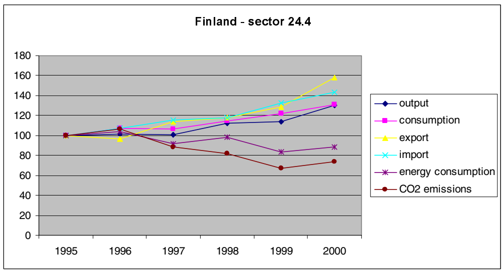


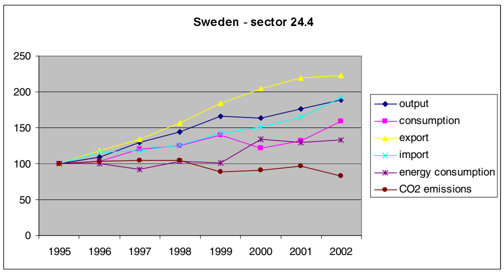


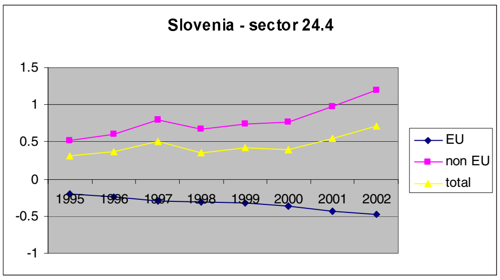


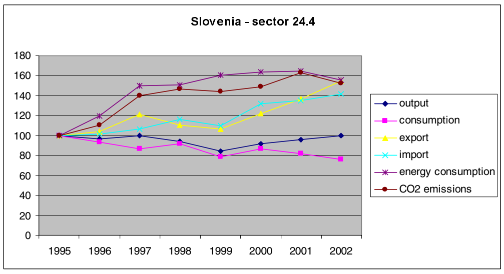




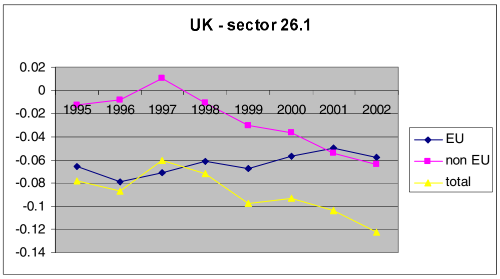


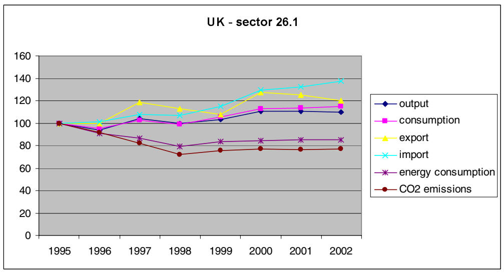


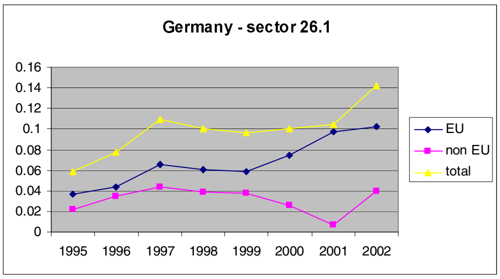


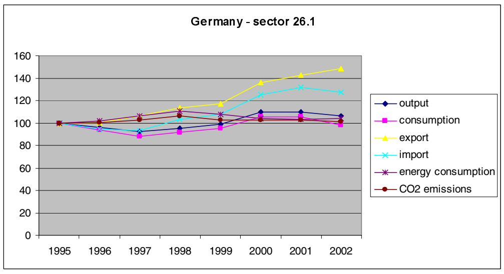


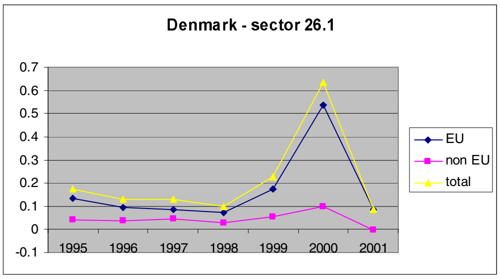
Sector 26.1: Glass and glass products

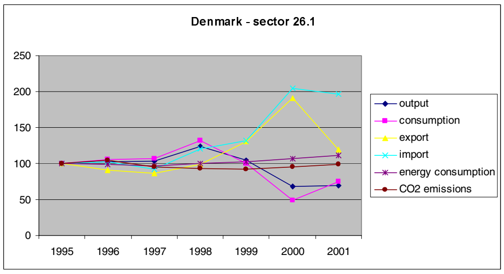


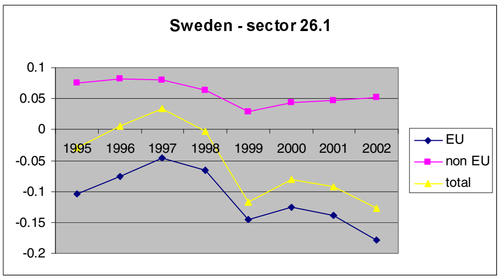


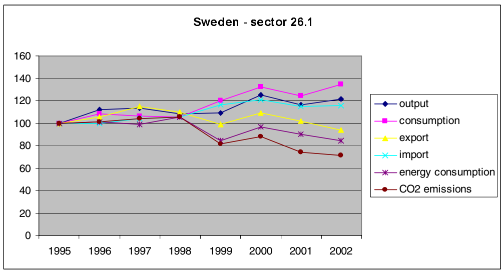


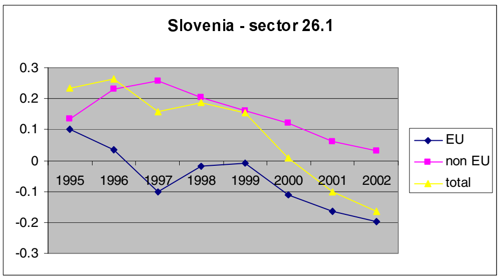


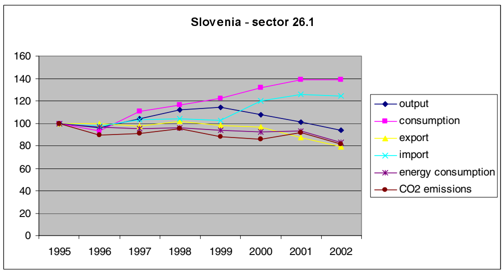




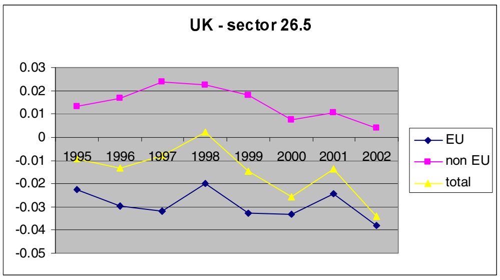


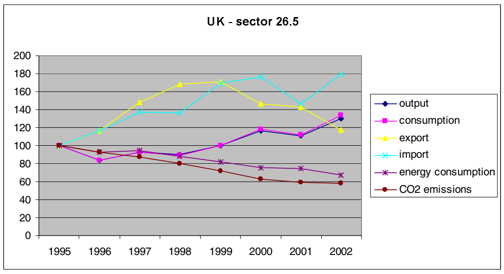


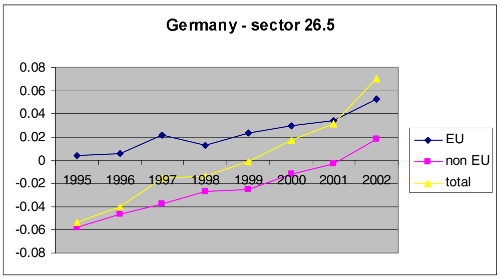


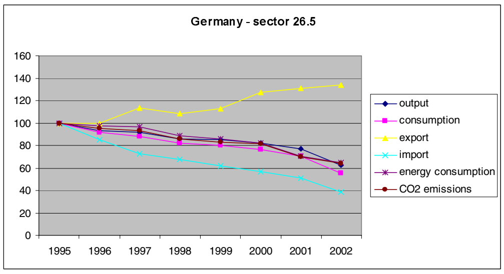


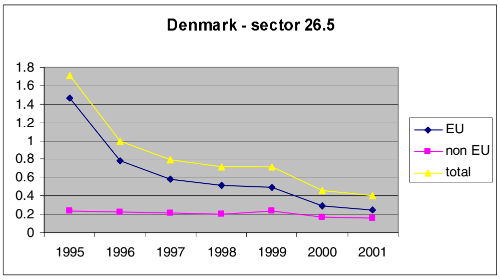
Sector 26.5: Cement, lime and plaster

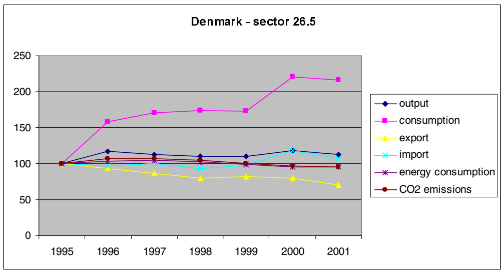


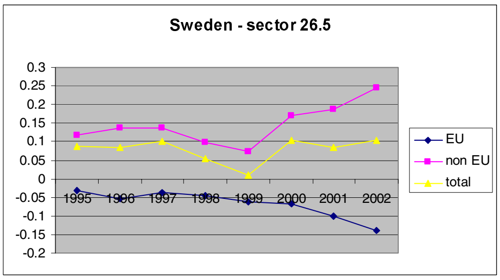


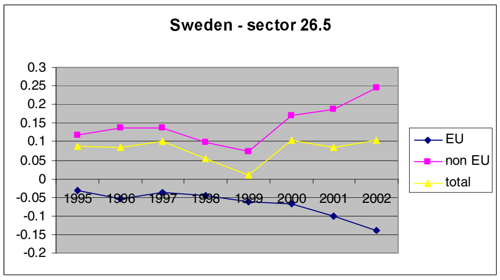


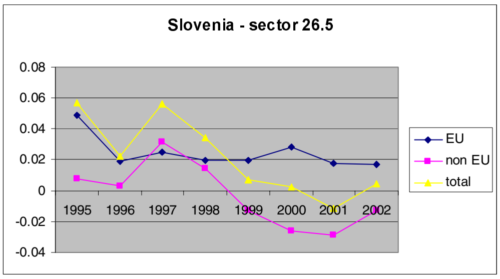


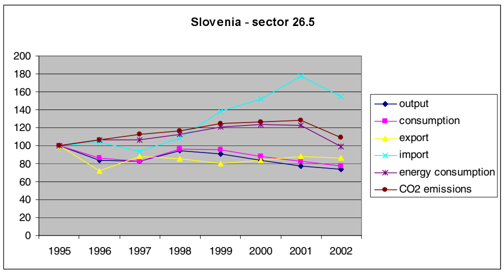




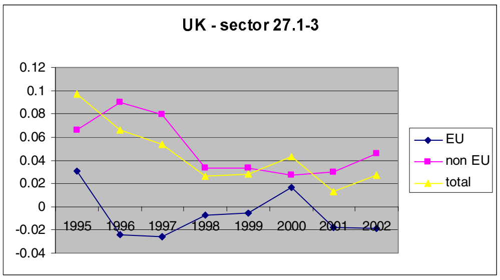


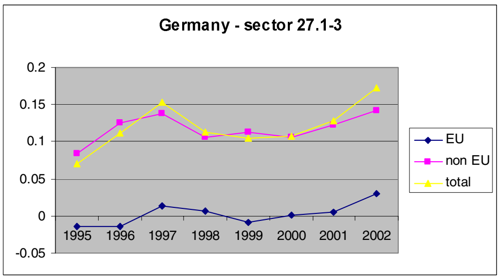


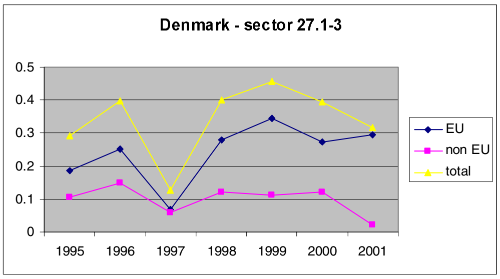


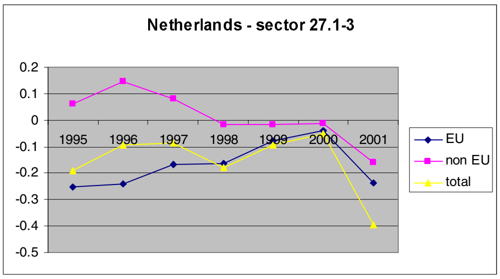


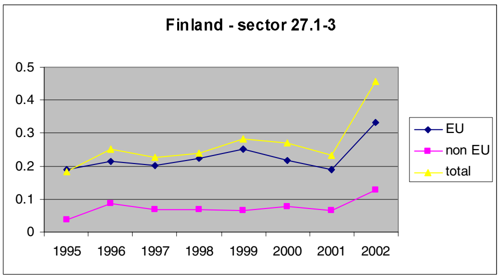
Sector 27.1-3: Ferrous metals

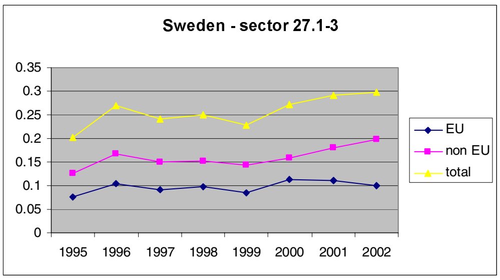


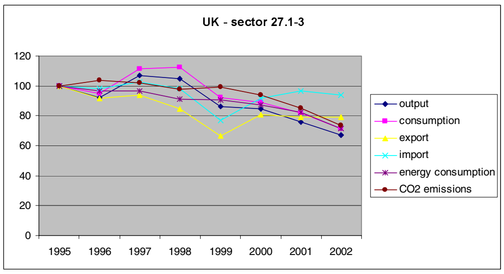


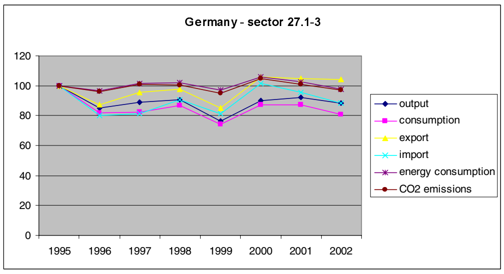


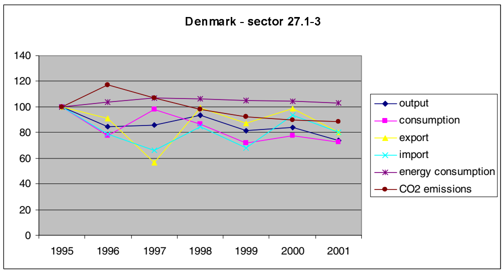


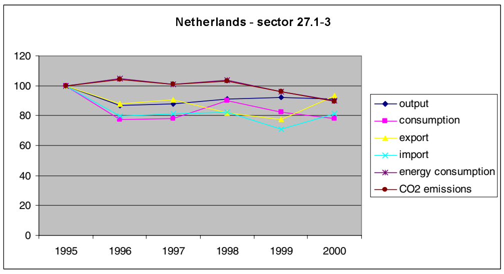


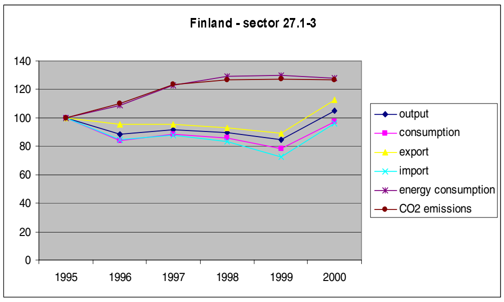


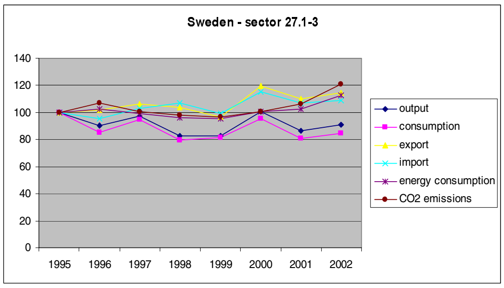


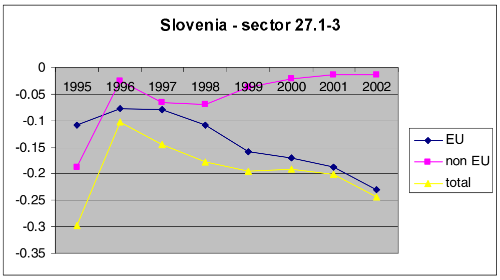


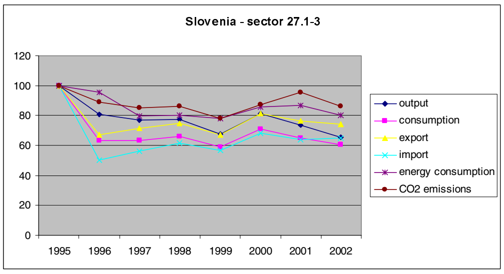




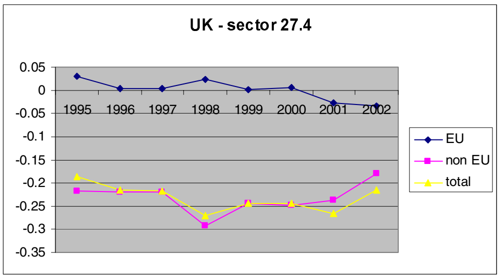


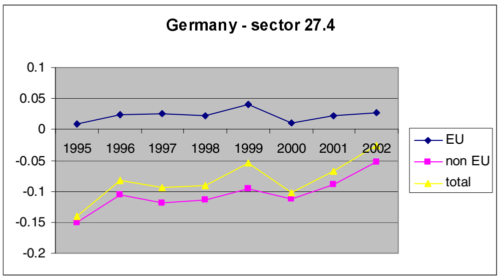


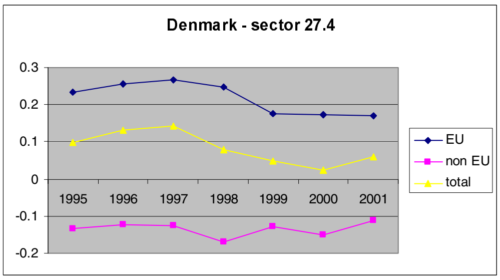

Slovenia - sector 27.1-3
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
1995 1996 1997 1998 1999 2000 2001 2002
EU
non EU
total

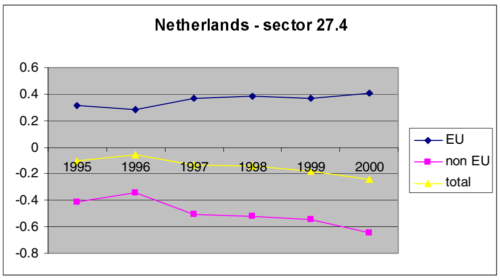

Slovenia - sector 27.1-3
120
100
80
60
40
20
0
1995 1996 1997 1998 1999 2000 2001 2002
output
consumption
export
import
energy consumption
CO2 emissions

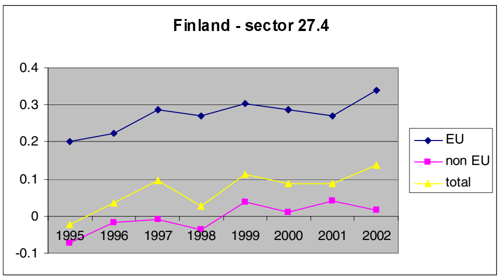
Sector 27.4: Non-ferrous metals

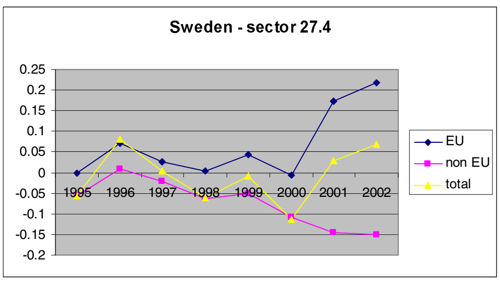


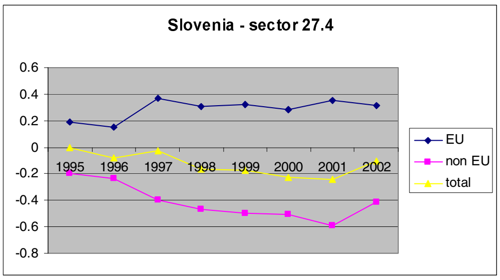


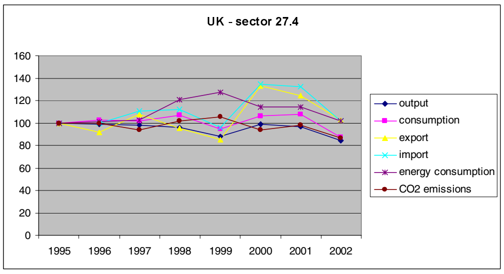


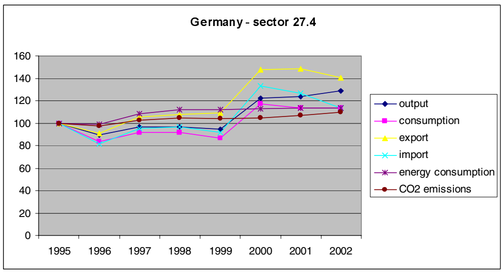


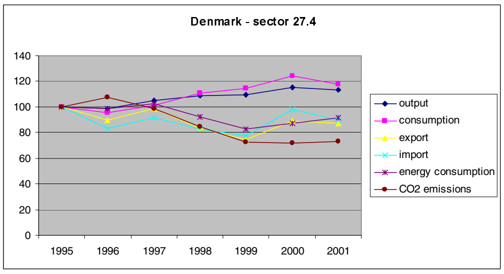


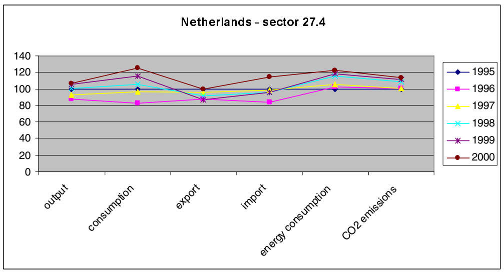


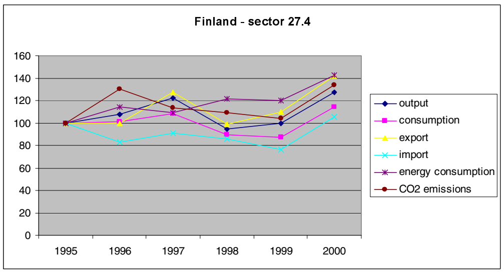

Slovenia - sector 27.4
0.6
0.4
0.2
0
-0.2
-0.4
-0.6
-0.8
1995
1996
1997
1998
1999
2000
2001
2002
EU
non EU
total

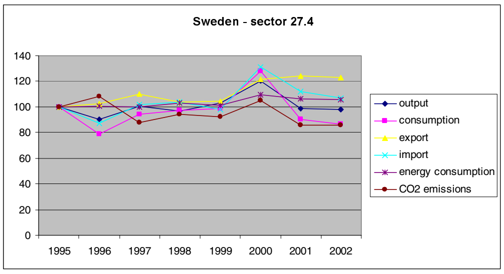

UK - sector 27.4
160
140
120
100
80
60
40
20
0
1995
1996
1997
1998
1999
2000
2001
2002
output
consumption
export
import
energy consumption
CO2 emissions

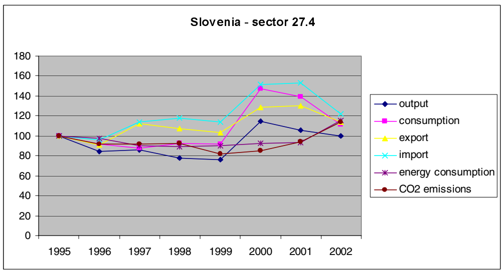

Germany - sector 27.4
160
140
120
100
80
60
40
20
0
1995
1996
1997
1998
1999
2000
2001
2002
output
consumption
export
import
energy consumption
CO2 emissions


Denmark - sector 27.4
140
120
100
80
60
40
20
0
1995
1996
1997
1998
1999
2000
2001
output
consumption
export
import
energy consumption
CO2 emissions


Netherlands - sector 27.4
140
120
100
80
60
40
20
0
output
consumption
export
import
energy consumption
CO2 emissions
1995
1996
1997
1998
1999
2000


Finland - sector 27.4
160
140
120
100
80
60
40
20
0
1995
1996
1997
1998
1999
2000
output
consumption
export
import
energy consumption
CO2 emissions


Sweden - sector 27.4
140
120
100
80
60
40
20
0
1995
1996
1997
1998
1999
2000
2001
2002
output
consumption
export
import
energy consumption
CO2 emissions


Slovenia - sector 27.4
180
160
140
120
100
80
60
40
20
0
1995
1996
1997
1998
1999
2000
2001
2002
output
consumption
export
import
energy consumption
CO2 emissions

Carbon Leakage:
Analysis within an E3ME framework

WP5

Terry Barker, Sudhir Junankar,
Hector Pollitt & Philip Summerton,
Cambridge Econometrics

connecting you to the future

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Executive Summary

- Carbon leakage is measured as the increase in CO_2 emissions outside the countries taking domestic mitigation action and then dividing by the reduction in the emissions of these countries. In the context of this study and the use of E3ME, the change in emissions in both Environmental Tax Reform (ETR) countries[1] and non-ETR countries[2] has been taken as the difference between the Baseline case, which includes revenue recycling, and the counterfactual Reference case.

- Studies of the effects of the Kyoto Protocol have shown carbon leakage (from tax and permit schemes that do not include ETR) in the range of 5-20% using static computable general equilibrium models (CGE). However, Sijm *et al* (2004) conclude that, in practice, carbon leakage from the implementation of the EU ETS is unlikely to be substantial because transport costs, local market conditions, product variety and incomplete information all tend to favour local production.

- In the period investigated in this study, 1994-2012, our results for ETRs in Europe show that carbon leakage is very small and in some cases negative[3]. The six Member States who implemented ETRs all recorded a reduction in CO_2 emissions when comparing the Baseline case to the Reference case. However, countries who did not implement ETRs did not record substantial increases in CO_2 emissions; in fact the increases were very small, furthermore in some cases negative carbon leakage was recorded, for example, whereby CO_2 emissions fell in both ETR and non ETR countries.

- As an indirect proxy measure for carbon leakage, it is instructive to examine the effects on exports and imports in both ETR and non ETR countries, particularly in energy-intensive industries, given the nature of the reform. If exports in ETR countries fell, or imports rose, this would provide evidence for possible carbon leakage. However, in support of the simple carbon leakage indicator, exports and imports in Germany and the UK remained largely unchanged.

- Both indirect and direct analysis of carbon leakage suggests that carbon leakage will not take place as a result of unilateral action to reduce carbon emissions through environmental tax reform. The main reason for this conclusion is that ETR has very little effect on non-ETR regions. In certain cases, due to technological spillover effects, as measured through increases in investment in some non-ETR Member States negative carbon leakage occurs, albeit to a small degree.

- The ETRs do not strongly affect industry prices, because the tax rates are small and because even in energy intensive industries, energy costs are a small proportion of total costs. As industry prices do not increase greatly, firms are able to absorb the additional cost or pass the cost on to the consumer. Only in competitive, export-driven markets does the small industry price increase, lead to a decrease in output in the UK and German Basic Metals industries.

[1] Countries who have undertaken Environmental Tax Reform (ETR) are Denmark, Germany, Finland, the Netherlands, Sweden, and the UK. Slovenia was included as an example of a new member state, as it implemented a carbon-energy tax, but not a full ETR.

[2] The remaining EU 25 countries who did not undertake Environmental Tax Reform.

[3] Negative carbon leakage can occur when, following unilateral environmental action on one country, a second country's carbon emissions fall. This is most likely to take place as a result of technological spillover.

However, the decline in industry output is small and does not provide strong evidence for carbon leakage.

1 Literature on carbon leakage

1.1 Theoretical literature

Carbon leakage is measured by taking the increase in CO_2 emissions outside the countries taking domestic mitigation action and then dividing by the reduction in the emissions of these countries.

The IPCC's *Second Assessment Report* (1995) found a high range of variation in leakage rates from world models for OECD action from close-to-zero to 70%. The *Third Assessment Report* (TAR) (2001) found that the range had narrowed to 5% - 20% but noted that these estimates come from models with similar treatment and assumptions and that they do not necessarily reflect more widespread agreement. The TAR found that international permit trading substantially reduces leakage. The TAR also considered spillover through the improvement in performance or reduction in cost of low-carbon technologies.

Over the last few years the literature has extended earlier analysis using equilibrium models to include effects of trade liberalisation and increasing returns in energy-intensive industries; and a new empirical literature has developed.

Equilibrium modelling of carbon leakage from the 1997 Kyoto proposal

Paltsev (2001) uses a static global equilibrium model GTAP-EG based on 1995 data to analyse the effects of the 1997 proposed Kyoto Protocol. He reports a leakage rate of 10.5%, within a sensitivity range of 5-15% covering different assumptions about aggregation, trade elasticities and capital mobility, but his main purpose is to trace back non-Annex B increases in CO2 to their sources in the regions and sectors of Annex B. The Chemicals and Basic Metals sectors contribute the most (20% and 16% respectively), with the EU being the largest regional source (41% of total leakage). The highest bilateral leakage is from the EU to China (over 10% of the total).

Kuik and Gerlagh (2003) using the similar GTAP-E model conclude that for Annex I Kyoto-style action "carbon leakage is modest, confirming an extensive set of earlier studies". They find that the major reason for the leakage is the reduction in world energy prices, rather than substitution within Annex I. They find that the central estimate of 11% leakage is sensitive to assumptions about trade-substitution elasticities and fossil-fuel supply elasticities and to lower import tariffs under the Uruguay Round. These sensitivities result in a range of 6% to 17% leakage.

In contrast to this consensus of global leakage for Kyoto-style action of about 10%, Babiker's (2005) paper presents findings that extend those reported in the SAR and the TAR. He extends a seven region, seven good and three industry global CGE model (similar to the other GTAP models except for the energy-intensive sector but with the earlier 1992 database). The distinctive extension is the inclusion of a treatment of increasing returns to scale and strategic behaviour in the energy-intensive industry. Assuming the adoption of the Kyoto Protocol by the OECD region, he presents four leakage rates, which depend on the assumptions adopted:

1. 20% for constant returns to scale and differentiated products (the Armington assumption)
2. 25% for increasing returns to scale (IRTS) and differentiated products
3. 60% for constant returns and homogeneous goods (HG)
4. 130% for the HG-IRTS combination

The main reason for the higher estimates is the inclusion of a treatment of increasing returns to scale and strategic behaviour in the energy-intensive industry. The 130% rate implies that OECD action leads to more global GHG emissions rather than less.

In assessing this high leakage finding it is important to understand the critical underlying assumptions.

1. The CGE model assumes a global social planner to maximise welfare, full information over space and time, perfect competition, and identical firms in each sector ('representative agents').
2. The composite energy-intensive good is treated as homogeneous. The high leakage rates come when the composite energy-intensive good has to pay carbon taxes or emission permit prices, and relocates abroad. The implicit assumptions of perfect substitution and no transport costs mean that production relocates without extra cost. However the composite good includes paper & pulp, chemicals and metals; so it is clearly very mixed in terms of technologies in supply and uses in demand. In fact, one country's production is not perfectly substitutable for that of another as assumed, since the mix will differ.
3. Increasing returns are included in only one sector. Adopting this assumption for the energy-intensive industry alone seems arbitrary since many other products are produced under increasing returns (electricity, machinery, vehicles, computers, software, and communications). Indeed the literature (eg McDonald and Schrattenholzer, 2001) does not emphasise the technologies used by energy-intensive industries. In consequence, given perfect substitution, all production is likely to relocate, depending on the assumed dynamics in the model, and with increasing returns, the production in the non-Kyoto countries will become more price competitive, hence the 130% leakage rates.
4. Adjustment to a new equilibrium is assumed to take place over many years (eg 18 years 1992 to 2010, when the calibrated base year is 1992 with a solution for Kyoto effects for 2010). In fact Kyoto action has largely taken place after ratification. For example, the EU emission trading scheme began in 2005. The result is a much shorter time for leakage than that assumed in the study. The structure of international trade has also changed substantially since the early 1990s, with developing countries, China in particular, becoming much more important in international trade.

The model shows that the energy-intensive industries will re-locate in response to the change in relative prices brought about by 28% carbon abatement below business as usual by 2010 (the paper does not state which policy is assumed). The result shows the potential for international trade to undermine unilateral environmental policies under special assumptions and conditions. In fact, mitigation action has tended to give preferential treatment to energy-intensive industries, and any trade quotas, eg steel quotas, will obstruct relocation.

The policy implications of such findings are that carbon leakage is potentially a serious threat to the effectiveness of mitigation policies. Special treatment of the energy-intensive sectors most affected reduces the threat, but also the overall benefits of the policies. The weakness of the equilibrium modelling is that it is based on one-year's data and assumptions such as global maximization of private consumption, homogeneous goods, constant returns to scale and perfect competition. The Babiker study shows that including increasing returns to scale in one sector in such models under an assumption of perfect substitution can lead to the wholesale transfer of that sector's output ie there are special conditions under which industries will re-locate.

However, such extreme results are not found in the empirical studies of carbon leakage as a general response to mitigation under the Kyoto Protocol.

Sijm *et al.*, (2004) summarise these modelling results. ‘Models provide a useful, but abstract tool for climate policy analysis; they are faced by several problems and limitations with regard to practical policy decision- making, including problems such as model pre-selection, parameter specification, statistical testing or empirical validation.’ (p. 14).

Empirical analysis of carbon leakage

Sijm *et al.*, (2004) also provide an empirical analysis of carbon leakage from energy-intensive industries. The authors argue that the simple indicator of carbon leakage is insufficient for policy making. The potential beneficial effect of technology transfer to developing countries arising from technological development brought about by Annex I action is substantial for energy-intensive industries, but has so far not been quantified in a reliable manner. ‘Even in a world of pricing CO_2 emissions, there is a good chance that net spillover effects are positive given the unexploited no-regret potentials and the technology and know-how transfer by foreign trade and educational impulses from Annex I countries to Non-Annex I countries.’ (p. 179).

In the empirical analysis of effects in energy-intensive industries there are many other factors besides the price competitiveness considered in the modelling studies reporting high leakage rates. They conclude that, in practice, carbon leakage is unlikely to be substantial because transport costs, local market conditions, product variety and incomplete information all favour local production. They argue that the simple indicator of carbon leakage is insufficient for policy making.

Using a detailed model of the world industry, Szabo et al. (2006) report production leakage estimates of 29% for cement with an EU ETS allowance price of €40/tCO_2. Leakage rates rise the higher the allowance price. More generally, Reinaud (2005) surveys estimates of leakage for energy-intensive industries (steel, cement, newsprint and aluminium) with the EU ETS. She comes to a similar conclusion and finds that with the free allocation of CO_2 allowances ‘any leakage would be considerably lower than previously projected, at least in the near term.’ (p. 10). However, ‘the ambiguous results of the empirical studies in both positive and negative spillovers ... warrant further research in this field’ (p. 179). Analytical studies of climate policy models that focus on the steel industry found that the stricter the climate policy, the higher the rate of carbon leakage. With carbon prices of around €10/t CO_2, rates of around 25-40% of carbon leakage from Annex I to non-Annex I countries were found due to the relocation of production. Two of the models also found that leakage was greater with increases in tax rates at low carbon prices compared with high prices.

However, there are uncertainties surrounding these models as they are not specified to consider whether elasticity of demand for products determines the location of production across countries. The models also try to estimate the impact of future climate change policies on the incidence of carbon leakage, rather than those in the past. Technological spillovers are also not represented from industrialised to developing countries, which are considered the most important market for technology implementation. These technologies reduce the demand for fuel use and therefore the level of CO_2 emissions. Thus, these models have not provided significant evidence that environmental regulation promote the relocation of high-polluting industries.

Sijm *et al.* (2004) also argued from their empirical analysis that environmental policy has not been a significant decision criterion for the location of investment and is not a key explanatory factor for investing in energy-intensive processes in developing countries, as the cost effects of environmental regulation are found to be small.

Past experience also suggests that shifts in production shares in the global market have not clearly been due to past environmental policy changes. This production shift has been driven by market size, growth in regional demand (due to developments in new markets and increasing demand in developing countries) and wage levels rather than by a decrease in competitiveness of industrialised countries compared with developing countries. This has been observed for the steel industry where strong demand for these products has seen a shift in production to the developing countries such as China. Even if relocation in production to developing countries occurs, industries, such as iron & steel, tend to use the most recent technology as this minimises planning costs and maintenance costs. Therefore it is not obvious that cost effects of environment policy are influential motives for relocation.

For the purpose of investigating carbon leakage within the EU, there is not enough literature on carbon leakage to warrant conclusions about the effects of climate change policies of one Member State on emissions elsewhere in the EU. The same arguments apply as to those between Annex I and non-Annex I countries in a global context, but technological transfer within the EU is likely to be easier, and the cross-border activities of multinationals are more extensive. Barker (1998) provides estimates of leakage from unilateral policy action by EU Member States for a 10% reduction in GHGs by 2010. These can be found in Table 1.1.

The results show that leakage can raise or lower emissions, but the estimates of leakage are very small in relation to the effects in the countries taking action.

TABLE 1.1: PROJECTIONS OF CO2 REDUCTIONS IN MEMBER STATES, 2010

	Difference from base case in mtC	
	Unilateral action internal to the Member State	Unilateral action in the rest of the EU
Belgium	-5.8	0.1
Denmark	-0.9	0.0
West Germany	-16.9	0.1
Spain	-8.0	-0.6
France	-14.7	-0.6
Ireland	-1.3	0.0
Italy	-13.1	-0.1
Luxembourg	-0.2	0.0
Netherlands	-2.5	0.1
Portugal	-1.0	0.0
United Kingdom	-14.9	0.3

Source(s): Barker, T. (1998) p.1094.

2 Carbon leakage in an E3ME framework

2.1 Overview of carbon leakage in E3ME

Carbon leakage is measured by the increase in CO_2 emissions outside the countries taking domestic mitigation action divided by the absolute reduction in the emissions of these countries.

$$CL = -\frac{\Delta CO2_N}{\Delta CO2_M}$$

where $\Delta CO2_M$ is the change in CO2 in countries taking mitigating action and $\Delta CO2_N$ is the change in CO2 in countries not taking mitigating action.

In E3ME $\Delta CO2_M$ is calculated by subtracting a baseline figure for CO2 from a counterfactual reference case (discussed below) for the six ETR regions in total. Similarly $\Delta CO2_M$ is calculated by subtracting the baseline figure for CO2 from a counterfactual case for any country or group of countries, where mitigation policies (ETR) were not pursued.

Carbon leakage is a 'negative spillover' effect and may occur through international trade in energy goods, international trade in other goods and services, international trade in factors of production or international interaction between government policies. In Sijm *et al.*, (2004), there is an extensive discussion of carbon leakage in the context of an increase in CO_2 emissions in non-abating countries due to the implementation of climate policies in Annex I countries.

The objective is to determine whether environmental taxes cause carbon leakage through the spatial relocation of production of energy-intensive goods to countries that have not implemented environmental tax reforms (ETRs). This should be observable through patterns in emissions, energy demand and in international trade.

2.2 Methodology of carbon leakage in E3ME

The methodology described is that used for modelling the environmental tax scenarios as discussed in the DL4.5[4] Chapters 3-4.The specific scenarios from the Report (see DL 4.5, Chapter 5) used for this work package are:

The 'Reference Case' is a counterfactual projection without the ETR (R for "reference"), but including current and expected developments in the EU economy, eg the EU ETS;

The 'Baseline Case'[5] is an endogenous solution of E3ME (B for "baseline") over the period 1994-2012. This scenario includes the ETR in each Member State to be covered by the project, exemptions or special treatment for the industries most affected and the compensating reduction in another tax (revenue recycling). This scenario is calibrated closely to the observed outcome through using historical data which includes the effects of ETR implementation (the historical part of the baseline).

Using E3ME to investigate the extent of carbon leakage for EU

To determine the extent of any possible carbon leakage, we must consider trade effects and technical change as well as carbon emissions. Environmental tax reforms in E3ME will flow through to exports and imports in countries with and without ETRs (and therefore to output) and to carbon emissions through the following mechanisms:

International trade between countries that have implemented ETRs and those countries that have not, will be affected by cost and price increases:

- Domestic input costs will increase in the countries with ETRs as a result of higher fuel costs and/or other environmental taxes. Higher input costs raise domestic prices for the products in energy-intensive sectors (but this is also dependent on the extent to which producers pass through the cost increases) relative to those produced in countries without ETRs. If domestic prices rise and the prices are set by the domestic market, this implies that the export prices of products also increase.
- As domestic prices increase, import prices become relatively cheaper for energy-intensive products (long-run price homogeneity[6] is assumed in E3ME).
- Higher export prices imply that other countries without ETRs become more competitive through relatively lower input costs (as there are no energy tax increases). This gives these countries a comparative advantage in energy-intensive products. This may result in the relocation of these industries to countries with less stringent climate-change policies, and we would expect that exports rise from these countries because of relatively lower prices of energy-intensive goods and to meet 'rest of the world' demand. These

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[4] Cambridge Econometrics 'The Effects of Environmental Tax Reform on International Competitiveness in the European Union: modelling in E3ME' a report (DL4.5) for COMETR forms the basis for this note on carbon leakage.

[5] The historical part of the baseline solution, used for ex-post analysis, covers the period 1994-2002 (or 2003) where the data were available at the start of the project in December 2004. The forecast component of the baseline solution to 2012, used for the ex-ante analysis, is derived from a combination of DG TRENS 'Energy and Transport Trends to 2030' and IEA's energy price assumptions given in the 'World Energy Outlook 2005' (see DL 4.5 Chapter, 7, section 7.1 for details).

[6] In E3ME all price effects are assumed to be relative in the long run.

countries also reduce their imports from countries with ETRs as a result of price effects.

Increased international trade may lead to higher demand for fuel inputs, and thus, CO2 emissions as a result of the following effect:

- Gross output is higher in countries without ETRs due to lower imports and higher exports but gross output is lower in countries with ETRs.
- Higher gross output from energy-intensive sectors in countries without ETRs may lead to higher energy demand (in production) and higher emissions. In contrast lower gross output and energy demand will lead to a reduction in emissions in non-ETR countries.

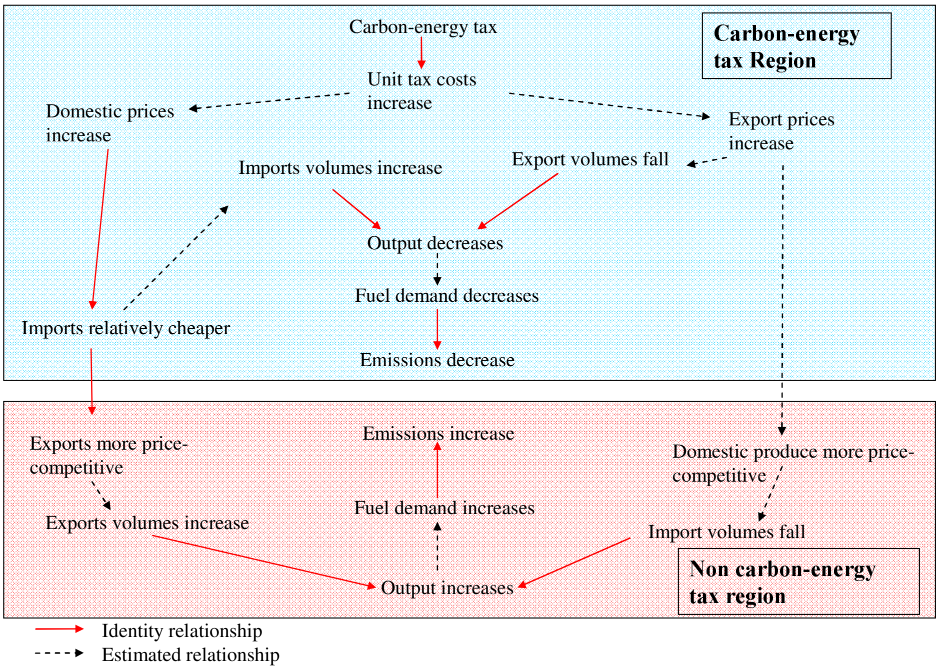
Figure 2.1 illustrates how the increases in energy and carbon taxes as components of ETR, working through these mechanisms, may lead to carbon leakage in E3ME. However, competitiveness of energy-intensive goods may improve in countries with ETRs if the policies induce innovation and reduce the energy-intensity of the associated industries. This innovation investment may impact carbon emissions in countries with and without ETRs through technological changes (not illustrated in Figure 2.1). We expect technological change to improve the quality of goods (particularly energy-intensive goods), increasing demand for these goods in domestic and international markets. The net impact that improvements in technological change have on CO2 emissions in countries with and without ETRs depends on:

- the level of increase in investment
- the willingness of customers to pay for the improved quality of goods
- increases in output due to higher net export demand for improved quality of goods arising from technological change incorporated in the new investment

In addition, Figure 2.1 only considers the tax effects on unit costs from the carbon/energy tax components of ETR and does not consider revenue recycling. Revenue recycling could have two different effects on the system illustrated in Figure 2.1. Firstly, revenue recycling could cause unit prices to fall in some sectors, in the case where revenues are used to reduce employers' social security contributions, as labour unit costs would fall. However the effects of this type of recycling will differ between industries and depend on the relative proportions of labour and energy in determining unit cost. For example, the services sector is likely to gain most from the inherent reduction in labour costs, as the services sector is labour intensive. However, the services sector has a low ratio of exports to output, so any offsets on carbon leakage are likely to be small.

Secondly, revenues from ETR may be used to reduce income tax; in this case output in the domestic industry could rise because of stronger consumer demand. In this second case carbon leakage might not occur because industries have no incentive to relocate, alternatively it may cause import demand to increase, as prices become relatively cheaper abroad, and therefore give rise to carbon leakage.

FIGURE 2.1: HOW CARBON LEAKAGE WOULD OCCUR IN E3ME



2.3 Limitations of E3ME in analysing carbon leakage

E3ME is *not* a world model, and as such the estimates only cover possible carbon leakage to other EU Member States that have not implemented ETRs, vis-à-vis those that have, and not to the rest of the world.

Estimates will be the leakages via price effects of ETR on energy-intensive industries raising costs so that non-ETR countries have greater price competitiveness in EU markets than those countries with ETR.

Results will include the effects of ETR improving non-price competitiveness of energy-intensive industries - higher investment leading to more exports and reverse leakage. This is an important finding in empirical studies.

Although the volumes for intra- and extra- EU trade can be identified, the same is not true for prices, and therefore the export and import price specifications in the model are for all imports and exports regardless of destination or source.

3 Estimates of Carbon Leakage as a result of Environmental Tax Reform in E3ME

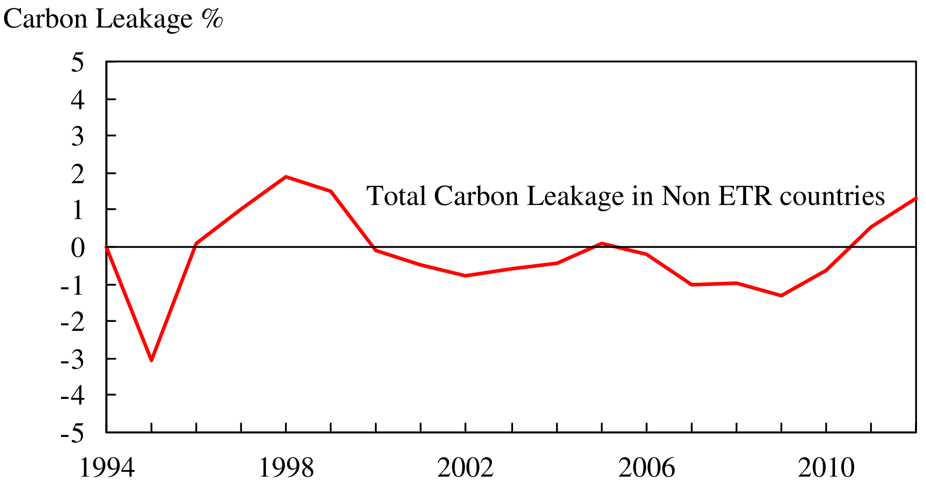
3.1 Direct analysis of carbon leakage in E3ME

In terms of total carbon leakage in non-ETR Member States the analysis undertaken as part of WP4 in the COMETR project is only able to assess the extent of carbon leakage as a result of the ETRs of the six countries collectively and not individually. Hence these results show the individual and collective changes in carbon emissions resulting from the collective tax reforms of the six ETR countries.

Chart 3.1 shows the total carbon leakage in non ETR countries as a result of ETR in the six ETR countries considered in WP4 (Denmark, Germany, Finland, the Netherlands, Sweden and the UK). In contrast to a large proportion of the economic literature our results show that carbon leakage is very small in the non-ETR countries as a whole. Carbon leakage fell in 1995 as a result of the ETR to -3%, but from that point on there was no significant carbon leakage (positive or negative) when comparing the Baseline case to the counterfactual Reference case.

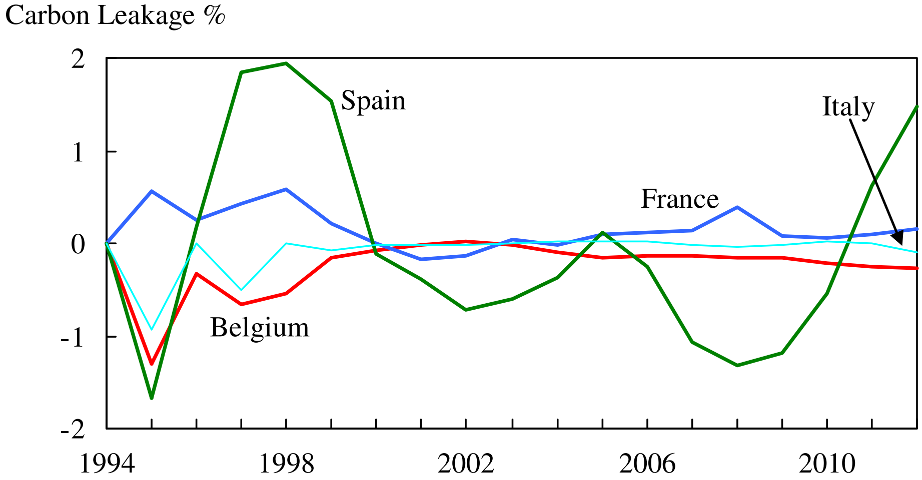
The results also show that in some years 'negative' carbon leakage was recorded, suggesting that there was a reduction in aggregated carbon emissions in both ETR countries and non ETR countries. This result is consistent with technological spillover effects. Whereas economic theory might suggest that an increase in fuel prices through an ETR would cause energy intensive industries to relocate to countries who have not imposed ETR, and hence lead to carbon leakage, it may in fact be the case that industry invests in energy efficient processes and technologies which are then exported to similar industries in the non ETR regions.

CHART 3.1: TOTAL CARBON LEAKAGE IN NON ETR COUNTRIES AS A RESULT OF ETR



Note(s) : Carbon Leakage is the change in carbon emissions in countries without ETR divided by the change in carbon emissions in ETR countries and expressed as a percentage.
Source(s) : CE.

CHART 3.2: CARBON LEAKAGE IN INDIVIDUAL NON ETR COUNTRIES AS A RESULT OF ETR



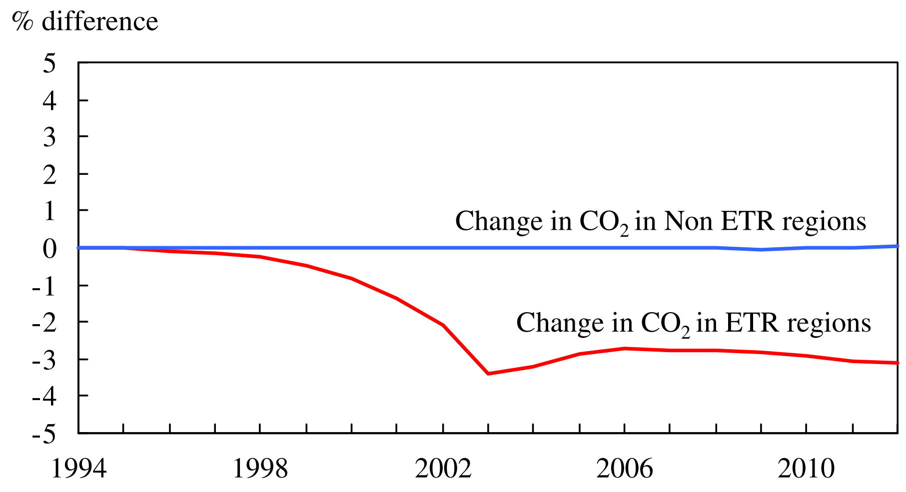
Note(s) : Carbon Leakage is the change in carbon emissions in countries without ETR divided by the change in carbon emissions in ETR countries and expressed as a percentage.
Source(s) : CE.

There are several other reasons why carbon leakage may not occur to the extent suggested in previous literature: the cost of relocation, both in terms of transport costs and the costs of finding new markets, may not outweigh the cost of investing in more efficient energy processes.

Chart 3.2 also provides evidence that carbon leakage in some of the largest non ETR regions individually was very small when comparing the Baseline case with the Reference case. This chart shows that in countries where relocation of energy intensive industries was most likely, namely, France, Spain, Italy and Belgium, carbon leakage varied between positive and negative over the period. The percentage of carbon leakage was, however, very small in all of these countries, varying between 2% and -2%. As discussed earlier negative carbon leakage can be explained by technological spillover within Europe and the transfer of new technologies.

The movement in carbon leakage, described in Chart 3.1, is also reflected by the carbon leakage in Chart 3.2 for Belgium, Italy and France. After the initial negative carbon leakage in 1995, carbon leakage then fluctuates around zero. In Spain a similar pattern is observed, however the fluctuations around zero are slightly more severe, although still between 2% and -2%, a fall is observed in 1998 followed by a rise in carbon leakage to just over 1% in 2008. Chart 3.3 shows the relative reduction in CO_2 emissions when comparing the Baseline case with the Reference case. As expected CO_2 emissions fall in the ETR countries collectively over the period by 3-4% in 2012 as a result of the ETR. In contrast the ETRs have almost no effect on the level of CO_2 emissions in non ETR countries. This suggests that there was no carbon leakage from ETR regions collectively to non ETR regions.

CHART 3.3: CHANGES IN CO_2 EMISSIONS IN ETR AND NON ETR REGIONS



Note(s) : % difference represents the difference between the baseline case and the reference case.
Source(s) : CE.

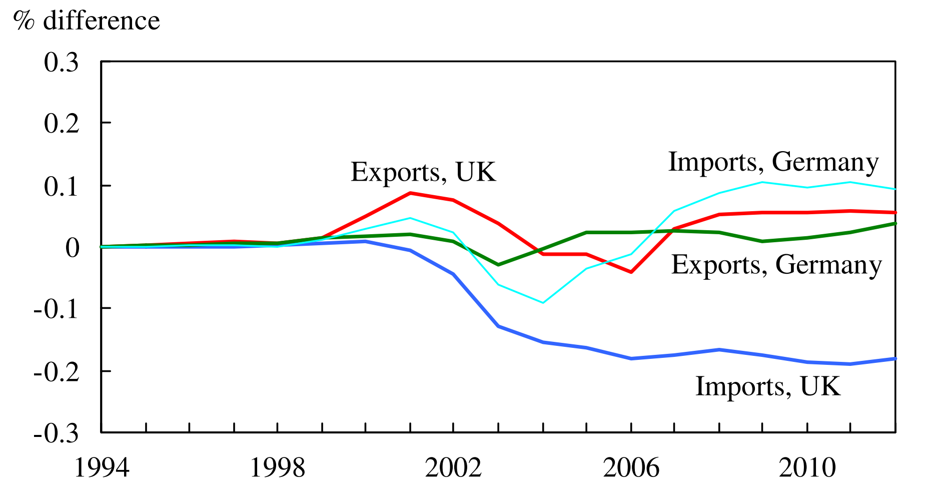
3.2 Indirect Analysis of Carbon Leakage in E3ME

Trade patterns will indicate whether carbon leakage has occurred by comparing between countries (and sectors) for:

- relative prices of energy-intensive products between countries (reflecting changes in comparative advantage)
- terms of trade (exports/imports) changes as a result of changes in relative prices
- ratio between the domestic price (which reflects whether increases in input costs are completely passed through to the end user) and export price of a product in the country introducing the ETR
- output changes arising from changes in trade patterns

Technical change will also indicate whether tax reforms have given incentives to promote investment in more energy-efficient technology. Technical changes may lead to higher quality products being exported from the country introducing the ETR and this may lead to import demand for these products in other countries even if the prices of imports from countries with ETRs in place are higher. On the other hand, CO_2 emissions may decline in both types of countries if technical improvements occur through positive spillover effects (via foreign direct investment) from the countries developing these technologies.

CHART 3.4: EVIDENCE FOR CARBON LEAKAGE IN EXPORTS AND IMPORTS IN THE UK AND GERMANY



Note(s) : % difference represents the difference between the baseline case and the reference case.
Source(s) : CE.

Chart 3.4 shows the effects of ETR on exports and imports of the two largest economies considered in WP4, Germany and the UK. This chart clearly illustrates that the ETR had very little effect on total intra-EU exports and imports in both Germany and the UK; the difference is between 0.3% and -0.3%, suggesting that it is highly unlikely that carbon leakage would occur given that there has been little effect on the terms of trade. If carbon leakage were taking place a fall in exports in both Germany and the UK would result as firms reinvested in non-ETR regions such as France, Spain and Italy or central Europe. In addition imports to ETR countries would increase if carbon leakage were taking place as imports would be relatively cheaper. This happens to a very small degree in Germany but the opposite is true in the UK.

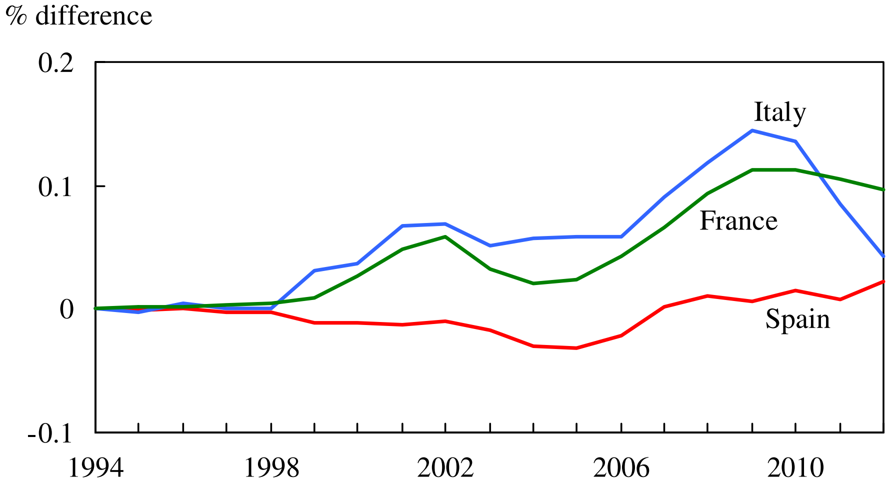
This is further evidence to suggest that carbon leakage does not occur as a result of unilateral[7] action regarding ETRs, and in fact goes slightly further to suggest that negative leakage occurs albeit by a small amount.

At the sectoral level the results are broadly consistent with the macroeconomic results; there is evidence for very small amounts of carbon leakage but in some cases this is negative. In Sweden, for example, exports of Wood & Paper are forecast to be 1.1% lower by 2012[8], as a result of the ETR, suggesting weak evidence for carbon leakage. On the other hand, the Basic Metals sector in the Netherlands is forecast to see an increase in exports of 2.1% in 2012 when comparing the Baseline case against the Reference case, suggesting efficiency improvements and investment. This appears to provide evidence contrary to part of the carbon leakage argument which suggests that exports will fall as firms will relocate to countries that have not imposed ETR, and where energy costs are therefore lower.

[7] Unilateral, in this case defines the ETR countries as having taken unilateral action when compared to the rest of Europe who did not undertake ETR.

[8] Refer to COMETR deliverable 4.5 Cambridge Econometrics, (2006) 'The Effects of Environmental Tax Reform on International Competitiveness in the European Union: modelling in E3ME'.

CHART 3.5: EVIDENCE FOR TECHNOLOGICAL SPILLOVER: INVESTMENT IN SPAIN, FRANCE, BELGIUM AND ITALY



Note(s) : % difference represents the difference between the baseline case and the reference case.
Source(s) : CE.

Furthermore, analysis showed that the ETRs had minimal effects on non-ETR countries. Further disaggregation of differences between the Baseline and Reference case highlighted the fact that ETRs have very little effect in non-ETR countries. Chart 3.5 shows that investment and induced technological improvements were minimal in non-ETR countries. Investment as a whole in France, Spain and Italy changed by less than 0.3% as a result of the ETRs, whilst this result is small it may well account for the small changes in CO_2 emissions in France and Italy. Investment in Spain remains virtually constant and does not provide evidence for the fluctuations in carbon leakage in Spain as a result of ETR.

3.3 Comparing the Effects on GDP and GHG in all EU25 Countries

Carbon leakage theory suggests that if carbon leakage is to take place, it will happen through changes to international trade in energy goods, international trade in other goods and services, international trade in factors of production or international interaction between government policies. This implies in terms of our analysis that if carbon leakage is taking place there will be a reduction in GDP for ETR countries when comparing the baseline case to the counterfactual reference case.

Table 3.1 clearly shows that GDP has increased in all of the ETR countries, albeit by a modest amount over the period modelled; this suggests that carbon leakage has not taken place. However, it is possible that due to the ETR the structure of the economy has shifted from energy intensive industry to non-energy intensive industry, and GDP has simply increased as a result of revenue recycling. In this case it is still entirely possible that energy intensive industries have relocated to non-ETR countries and hence carbon leakage can be said to have occurred.

TABLE 3.1: THE EFFECTS OF ETR: GDP IN EU 25

	2000	2004	2008	2012
ETR Countries				
Denmark	0.05	0.24	0.34	0.43
Germany	0.05	0.05	0.29	0.39
Netherlands	0.00	0.11	0.18	0.27
Finland	0.47	0.91	0.51	0.50
Sweden	-0.08	-0.15	0.14	0.52
United Kingdom	0.02	0.01	0.06	0.09
Selected non-ETR EU15				
Austria	0.02	0.03	0.07	0.06
Belgium	0.02	0.02	-0.05	-0.08
France	0.01	0.01	0.05	0.03
Italy	0.00	0.02	0.06	0.06
Portugal	0.00	-0.02	-0.01	0.02
Spain	0.01	0.02	0.03	0.05
Large NMS				
Czech Republic	0.01	-0.01	0.00	0.00
Hungary	0.01	0.01	0.01	0.01
Poland	0.01	0.02	0.02	0.03
Slovenia	0.16	0.03	0.07	0.01
Slovakia	0.02	0.01	0.02	0.00
Total EU 25	0.02	0.04	0.12	0.16

Note(s) : difference is the % difference between the baseline case and the counterfactual reference case.

However Table 3.2 shows how little greenhouse gas emissions vary as a result of the ETR in the EU25 countries. This suggests that very little carbon leakage has occurred. France and Spain are the only regions where greenhouse gas emissions increase as a result of ETR action in the ETR countries, there is therefore carbon leakage from the ETR countries to France and Spain, but not to any other EU25 country by 2012. However, the carbon leakage suggested in 2012 is very small, when compared with previous studies using static CGE modelling which suggest that carbon leakage might be as high as 20%.

A key point that arises from the tables, which is discussed in more detail in the COMETR DL 4.5 report[9], is that for the EU as a whole, GDP increases by 0.16% by 2012, whilst greenhouse gases are 1.3% lower, when comparing the baseline to the reference case.

[9] Cambridge Econometrics 'The Effects of Environmental Tax Reform on International Competitiveness in the European Union: modelling in E3ME' a report (DL4.5) for COMETR.

TABLE 3.2: THE EFFECTS OF ETR: GHG IN EU 25

	2000	2004	2008	2012
ETR Countries				
Denmark	-3.46	-3.63	-2.30	-3.43
Germany	-0.69	-3.73	-2.68	-3.45
Netherlands	-0.52	-1.46	-1.65	-2.01
Finland	-3.98	-5.90	-4.34	-5.23
Sweden	-3.80	-3.47	-6.35	-6.63
United Kingdom	-0.12	-2.02	-2.42	-1.97
Selected non-ETR EU15				
Austria	0.00	0.02	0.05	0.05
Belgium	-0.01	-0.05	-0.08	-0.13
France	0.00	-0.05	-0.11	0.19
Italy	0.00	0.00	0.00	-0.01
Portugal	0.01	0.00	0.01	0.01
Spain	0.00	0.01	0.08	0.03
Large NMS				
Czech Republic	0.00	0.01	0.01	-0.02
Hungary	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00
Slovenia	-0.05	-0.05	-0.10	-0.13
Slovakia	0.00	0.00	0.00	0.00
Total EU 25	-0.34	-1.47	-1.15	-1.29

Note(s) : difference is the % difference between the baseline case and the counterfactual reference case.

Our results show that very little carbon leakage has taken place at an aggregate level, and where it has taken place, from ETR countries to France and Spain, the leakage has been very small. To investigate fully whether or not carbon leakage has occurred, at any level, it is necessary to examine the sectoral disaggregation. This is done in the next section.

3.4 Sectoral Evidence for Carbon Leakage

Although at the aggregate level there appears to be very little evidence for carbon leakage, and in fact in many cases negative carbon leakage occurs, it is necessary to assess at a more disaggregated level whether or not there has been any relocation of trade or factors of production for energy intensive industries.

The COMETR project looks at a number of NACE 3 digit level industries, as this is not possible within the E3ME framework, this paper examines the effects of the NACE 2 digit level industry classifications (with an additional split for Pharmaceuticals and Chemicals nes). The COMETR project focuses on four of the most energy-intensive E3ME sectors, plus Food, Drink & Tobacco and Pharmaceuticals to provide a comparison. These are defined in Table 3.3 below at the NACE 2-digit level.

TABLE 3.3: DEFINITION OF COMETR SECTORS

E3ME Sector	NACE Definition
5 – Food, Drink & Tobacco	15, 16
7 – Wood & Paper	20, 21
10 – Pharmaceuticals	24.4
11 – Chemicals nes	24 (ex 24.4)
13 – Non-Metallic Mineral Products	26
14 – Basic Metals	27

Before analysing the individual sectors, it is worth looking at what proportion of inputs comes from energy. This has been covered more extensively in Work Package 3, Table 3.4 shows the proportions used in the E3ME model and suggests that even in the most energy intensive sectors, energy does not represent a large share of inputs. The values are formed by using the coefficients in E3ME from the base year (2000) input-output tables and are a share of gross output (so wage costs and profit are included in the denominator).

These are the sectors which, it is expected, will face the largest increases in energy costs, and therefore may face the biggest threat from the ETRs.

We would not expect to see much impact on these sectors in the regions where a large proportion of the tax increases fall on households (ie The Netherlands and Sweden). It should also be noted that firms in these industries will benefit from lower wage costs in regions where there is revenue recycling through employers' social security contributions. Finally, the effects of higher overall growth rates in each country (and the rest of Europe) will give a further boost to product demand.

TABLE 3.4: ENERGY COSTS AS A SHARE OF TURNOVER (%)[10]

	DK	DE	NL	FI	SW	UK	SI
Food, Drink & Tobacco	1.5	2.0	1.5	1.4	1.0	1.5	1.9
Wood & Paper	1.9	3.3	2.9	5.1	3.7	3.0	6.5
Pharmaceuticals	0.4	7.2	0.0	6.5	0.3	0.9	0.0
Other Chems	4.2	6.5	17.5	8.9	8.4	3.9	4.3
Non-Metallic Minerals	5.4	5.8	4.2	3.5	4.4	4.4	8.9
Basic Metals	3.0	8.7	5.8	6.6	4.5	4.7	9.4

Source(s) : CE, E3ME database.

[10] Figures for the Pharmaceuticals and Other Chemicals sectors are estimates (except for the UK) as these sectors are not explicitly defined at the NACE 2-digit level. These estimates are derived by summing across the rows and columns of the input-output table and taking relative gross output shares. For Germany and Finland the allocation of fuel use to Pharmaceuticals seems unreasonably high and it is likely that most of this demand should in fact have been allocated to Other Chemicals. For The Netherlands, the share seems too low, and the share of Other Chemicals too high.

Price increases

If energy represents around 5% of an industry's input costs (turnover – profit), then even a 50% increase in energy costs is going to lead to only a 2.5% increase in total input costs – even assuming that the industry is unable to reduce its fuel consumption or substitute between different fuel inputs. This may or may not be absorbed by firms within the industry (if there were perfect competition within the industry it would be completely absorbed, if there were no competition it would be completely passed on). The effect of any price increases will depend on the relevant price elasticities (domestic and export) for the industry's products. Typically these would be less than one, so a 2.5% increase in prices would not lead to a 2.5% decrease in product demand. Consequently, even in the energy-intensive sectors we would not expect to see large falls in output. This will be partially compensated by revenue recycling measures. Therefore, carbon leakage is unlikely to take place, simply because the rise in unit costs, even in energy-intensive sectors, is so small.

Table 3.5 shows the results for 2004. This year was chosen because it is the final data-point in the input series; by 2004 the ETRs are in place, but there is no blurring of results by the assumption that tax rates remain constant in real terms after 2004.

As expected, the largest increases in prices are in the Non-Metallic Mineral Products and Basic Metals sectors. Prices fall in the Wood & Paper sector (which operates in an EU market rather than national markets). This is mainly due to a reduction in labour costs in the sector (which form a much larger share of input costs than energy does), and this reduction is mainly a result of reductions in social security payments in Germany and the UK.

Only two of the sectors show price rises above 1%. These are both in Sweden, where the effects are actually an indirect result of higher consumer prices, particularly in electricity (from the ETR) which in turns leads to an increase in wages. In most other cases (excluding Wood & Paper) the differences are in the range of 0.2-0.4%. The increases in industry prices do not justify the cost of relocation to industry, which is consistent with findings that carbon leakage is not discernable at the aggregate level.

In most cases the price increases also include a factor for an increase in investment. This mainly represents firms' decisions to purchase new machinery in response to higher energy prices. While this may have a negative short-term effect in price competitiveness, it will improve long-term non-price competitiveness through the production of higher-quality output (which may again command higher prices).

TABLE 3.5: CHANGE IN INDUSTRY PRICES, 2004

(% difference of baseline from reference case)

	DK	DE	NL	FI	SW	UK	SI
Food, Drink & Tobacco	0.01	0.05	0.00	0.46	1.69	0.00	0.04
Wood & Paper	-0.57	-0.40	-0.34	-0.26	-0.33	-0.48	-0.32
Pharmaceuticals	0.01	-0.09	-0.01	0.87	0.05	0.09	-0.02
Other Chems	0.32	0.72	0.11	0.36	0.28	0.36	0.08
Non-Metallic Minerals	0.33	0.46	0.26	0.77	1.06	0.29	0.16
Basic Metals	0.51	0.43	0.50	0.53	0.48	0.62	0.46

Changes in output The effects of the ETRs on industry output are less easy to interpret because they include a number of different factors:

- price effects outlined above
- non-price effects from additional investment
- consumer demand
- activity in export markets
- production in competing import markets

Table 3.6 shows the percentage increase or decrease in gross output for each of the examined industries, again in 2004. The results suggest that, in many cases, the over-riding effect is higher domestic demand from consumers.

In most cases, gross output in the affected industries increases slightly. This is not entirely unexpected given the modest nature of the price increases recorded. The scale of the increases varies across sectors much more than across countries. The smallest differences are in the UK where the impact of the ETR was smallest. This suggests that carbon leakage is not taking place, even at the sectoral level as output is not relocating away from ETR regions as a result of the tax. Only in a highly competitive, export-driven market does the small industry price increase lead to a decrease in output, the UK and German Basic Metals industries. The absence of strong evidence for carbon leakage is mainly due to the fact that the ETR energy taxes are relatively small and so, they do not have a large enough effect on unit cost to justify the cost of relocation.

TABLE 3.6: INCREASE IN INDUSTRY GROSS OUTPUT, 2004

(% difference of baseline from reference case)

	DK	DE	NL	FI	SW	UK	SI
Food, Drink & Tobacco	0.65	0.56	0.13	0.64	4.24	0.02	0.28
Wood & Paper	0.29	0.17	-0.27	0.06	0.19	0.04	0.04
Pharmaceuticals	0.08	-0.02	-0.06	0.14	-0.05	0.00	-0.04
Other Chems	0.03	0.00	0.00	0.31	0.46	-0.07	-0.07
Non-Metallic Minerals	0.08	-0.28	0.05	0.54	0.31	-0.03	0.02
Basic Metals	0.08	-0.15	0.63	0.08	0.08	-0.16	0.00

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An Economic Criterion for Carbon Leakage

WP5

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Abstract

This paper proposes a simple economic criterion for assessing carbon leakage and applies it empirically on a sample of European countries. After reviewing possible definitions of carbon leakage, and distinguishing between an absolute form of carbon leakage and a relative form of carbon leakage, a theoretical assessment is made of which economic measure could be suitable for detecting carbon leakage in the absence of emissions data. Net import penetration is first assessed, but is found to pose problems in certain cases. A new indicator is then found which provides better properties from a theoretical point of view. This indicator is then used in an empirical assessment of carbon leakage for 13 European Union countries over the 1991-2003 period. In particular, an empirical model is estimated with the goal of differentiating between those countries that had, during that period, introduced environmental tax reforms (ETR) and those that had not, and between manufacturing as a whole and its more energy-intensive component industries. Leakage is found to have occurred in all but one country in the case of manufacturing as a whole and in all but two in the case of energy-intensive industries. However this leakage is found to have been driven by increased trade liberalization and integration at both the European and global levels, not by ETR, which is found to have had no significant effect.

JEL Classifications: F14, F18, Q56

Keywords: trade, carbon leakage, import penetration, environmental tax, ETR

Introduction

A key issue in environmental economics is that of carbon leakage. Carbon leakage is usually defined in quantitative terms as the ratio between abating countries' reduction in CO2 emissions (or equivalent) and non-abating countries' increase in CO2 emissions. This definition has been used extensively in the environmental economics literature, in particular in the context of ex-ante modelling exercises that seek to assess the impact of abatement policies when undertaken by certain countries but not by others. Just two examples of such approaches are Paltsev (2001) and Kuik and Gerlagh (2003), the former including a regional and sectoral breakdown of leakage, and the latter including additional modelling of the effect of international trade liberalization under WTO agreements. Crucially, these modelling approaches are based on a comparison between a baseline scenario, say one without any abatement measures, and a tested or assessed scenario which assumes specific abatement measures. In this way the idea is to capture changes in emissions that are due to the abatement policies per se, not to other factors. The result of this definition of carbon leakage is that abatement policies may be considered an environmental failure if the leakage ratio is greater than 1, a success if the leakage ratio is strictly below 1, and indifferent in its (global) outcome if the leakage ratio is equal to 1.

This study aims to provide some theoretical elements for, and an empirical example of, an ex-post assessment of carbon leakage using only economic indicators. This is not to suggest that such assessments should be made using only economic indicators, but rather that, given the data availability constraints that may arise in practice, it seems worthwhile to assess how much can be said about carbon leakage when economic indicators are the only ones that are available.

For this purpose it is useful to consider the definition of carbon leakage. The generally accepted definition of leakage is suitable in the context of modelling exercises where all parameter values are present (either estimated or assumed). Wholly different difficulties arise in an ex-post analysis based on empirical observations. Conceptually the difference is clear: there are no scenarios to compare, only past empirical reality to assess. However the core idea of carbon leakage remains: an abatement policy in a given country should be deemed to be a failure from a global environmental viewpoint if, in spite of causing reductions in emissions at home, it causes a rise in emissions abroad that is larger in absolute value. In other words a criterion (or threshold) for undesirable carbon leakage could be defined as a shift in the geographical origin of production that is such as to increase the total carbon emissions that are related to home market consumption. This one may choose to call *absolute carbon leakage*, in the sense that if the carbon leakage ratio defined earlier is greater than 1 then one would say that there has been absolute carbon leakage.

However the problem with such a definition if applied to historical data is that it may not be at all clear what the effect of the abatement policy actually was. Realistically the only thing that one can be sure about ex-post is what happened to economic indicators such as output and trade and, provided one has fairly precise estimates of the corresponding carbon intensities, emissions. If emissions data isn't available, as will be assumed from now on, then one only has economic indicators at one's disposal. At this stage it therefore seems useful to distinguish between scale and efficiency effects. In a context of ongoing economic growth (rising scale) one would hope to see a reduction in carbon intensity (improved efficiency). This phenomenon is called decoupling and is the subject of intense research efforts in its own right. However, as far as leakage is concerned, one could therefore formulate an alternative definition, which one may choose to call *relative carbon leakage*, which would assess changes in carbon intensity. In the context of falling total emissions this criterion would be generally *more demanding* from an environmental viewpoint than absolute carbon leakage, and could be expressed as a shift in the geographical origin of production and of related carbon emissions that is such that total carbon emissions decrease, but less than the corresponding decrease of the country's domestic emissions. In those cases where total emissions actually increase, the relative carbon leakage criterion would nevertheless retain its value as an indicator of efficiency, although absolute carbon leakage will have taken place.

For now we will proceed with relative carbon leakage as equivalent to an increase in the overall carbon intensity of domestic consumption[1]. This definition will be discussed again in a subsequent section. In order to illustrate both proposed definitions of carbon leakage fictitious numerical examples are shown in table 1.

Table 1 – Simplified illustration of carbon leakage

Domestic production	Net Imports	Domestic consumption	Total carbon emissions	Leakage	Domestic emissions	Foreign emissions	Total carbon intensity
1000	**200**	**1200**	**2600**	**Starting point**	**2000**	**600**	**2.167**
800	400	1200	2800	Absolute leakage	1600	1200	2.333
800	360	1160	2680	Absolute leakage	1600	1080	2.310
800	300	1100	2500	Relative leakage	1600	900	2.273
1100	100	1200	2500	No leakage	2200	300	2.083

Source: own calculations

The first row in table 1 represents the starting point in the first of two time periods. In a given country (e.g. an EU member state), for a given industry, there is a production level of 1000 tonnes of a particular commodity. A further 200 tonnes are acquired through net imports, so that domestic consumption amounts to 1200 tonnes. We assume for the moment that there are no exports from the home country, so that net imports and imports are equal. We also choose to ignore the part of foreign production which is destined for foreign consumption. The carbon intensity of the production process is assumed to be higher in the foreign countries, e.g. countries not party to the Kyoto protocol. It is assumed in this example that carbon intensity is equal to 2 kg of CO2 equivalent per tonne of domestically-produced goods, but is equal to 3 kg of CO2 equivalent per tonne of foreign-produced goods. The result in terms of emissions in the starting point situation is 2600 kg of CO2 equivalent. As for the last column, it indicates overall carbon intensity, defined here as total carbon emissions divided by domestic consumption. The four rows below represent different possible outcomes for the second period, showing which ones lead to carbon leakage. In the first case, as described in the 2nd row, domestic consumption stays constant, but a larger share of it is provided for from net imports. This is clearly a case of absolute carbon leakage, as total emissions rise while domestic consumption remains the same. The second case in the 3rd row is also a case of absolute carbon leakage. This time however domestic consumption actually decreases, but this is more than offset by the higher share of imports, so that total emissions go up as compared to the starting point scenario. The third case, in the 4th row, is particularly interesting. Here we have a case of relative carbon leakage. Total emissions go down, because the decrease in domestic emissions due to decreased domestic production is larger than the increase in foreign emissions due to the increase in net imports. However because a larger share of total consumption is now accounted for by the more carbon-intensive production that goes on abroad, overall carbon intensity has increased. Finally in the last row we have a case without leakage, in spite of a rise in domestic emissions due to a rise in domestic production. Note that in the examples above it was assumed that the domestic and foreign carbon intensities do not change.

Given this basic context it is perhaps relevant as a conclusion to this introduction to briefly discuss the related issues of relocation of production and the pollution haven hypothesis. While environmental policies such as a carbon tax or capping and trading of carbon emissions provide, ceteris paribus, an economic incentive to agents which should ultimately drive down carbon intensity in a country which adopts such policies, it is equally clear that countries that do not introduce such policies create no such incentives for their domestic producers and, further, that production may shift from environmentally-friendly countries (EFCs) to non-environmentally-friendly countries (NEFCs).

[1] Defined here as domestic emissions plus the emissions due to the part of foreign production that is exported to the reference country, divided by domestic consumption.

Production can shift in a number of ways. The clearest case is if production facilities relocate from EFCs to NEFCs. Such shifts would hence be associated with foreign direct investment (FDI) flows, and if such investments are primarily of the relocation type, and primarily driven by differences in environmental taxation and regulation, then one would be in the presence of the so-called *pollution haven hypothesis*. This would clearly result in carbon leakage. However, as we have seen, leakage may also arise simply if the share of EFCs consumption accounted for by imports from NEFCs rises, if it is indeed the case (as one would normally assume and as was assumed in the illustration given in table 1) that carbon intensity is higher in NEFCs on average.

Assessing the pollution haven hypothesis (PHH) per se is an extremely challenging task. It would require detailed FDI data, not only on the investment flows themselves, but also on why the investments took place. As is known from the literature on FDI, e.g. starting with Dunning (1977), there are several types of advantages to FDI, of which locational advantages. In the context of the PHH the idea would be that firms save on the costs inherent to environmental regulation and taxation. However other locational advantages are cited much more often in FDI studies and in surveys of firms, notably wage cost differentials and better access to destination markets. In particular Brainard (1997) distinguishes between two main types of FDI: horizontal or market-seeking FDI and vertical or efficiency-seeking FDI. The former is primarily driven by the firm wanting to have better access to the foreign market, so that trade reversal (exporting back to the country of origin) is not particularly prevalent, if at all, in such cases. The latter, vertical FDI, is primarily driven by cost differences between the country of origin of the firm and the country in which it invests. This second type of FDI is the type that the public has in mind when there is talk of “Asian sweat-shops”, e.g. the classical case of clothing articles, where wage differentials are such that a Western multinational will find it profitable to produce in Asia and export a substantial share of the production to its home market in Europe or North America. A theoretical framework for this type of FDI can be found in Helpman (1984). Clearly it is this second type of FDI which may, conceivably, provide the background for the PHH. However one would then find that environmental taxation and regulation (or rather the lack thereof) would be only one of several locational advantages for investing firms. Because the quality and stringency of environmental standards tends to be highly correlated with countries’ average income and wage levels it may be difficult to disentangle the effect of each from the other in an empirical study.

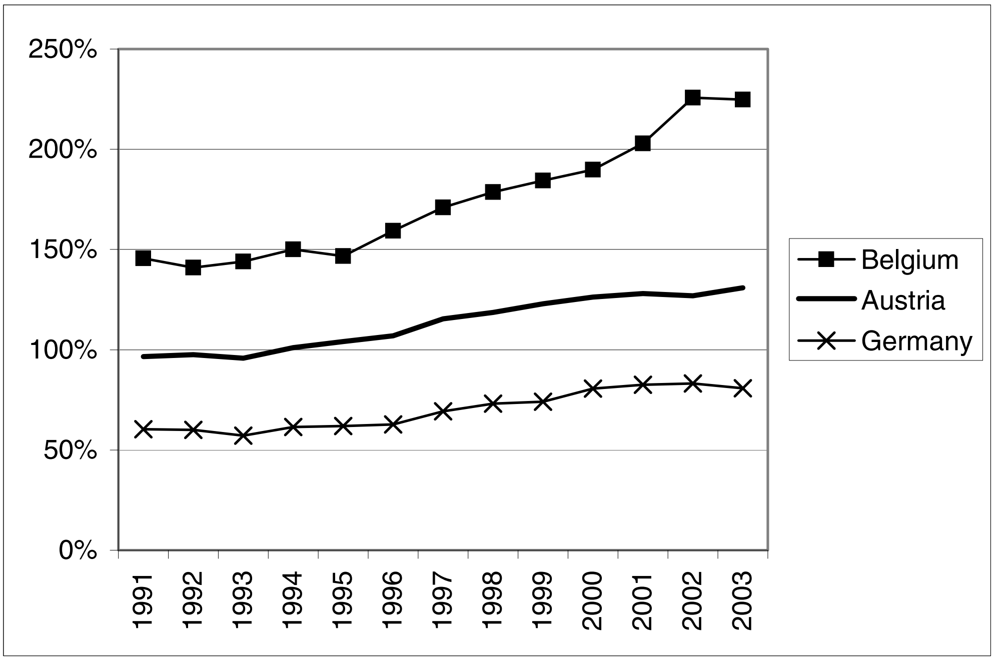
For these reasons this study will limit itself to an assessment of leakage based on production and international trade data, forgoing the (in my view) nested and ultimately non-essential issue of PHH relocation. After all, whatever happens in terms of FDI flows, trade and domestic consumption data should ultimately reflect whether or not leakage is at all happening, and if it is, to what extent. In fact an approach based on those variables is more general, as it can also account for shifts in the international distribution of production and consumption that does not result from relocations of production facilities, e.g. if consumption rises and most or all of the increase is met by imports, implying a lack of domestic investment in new production facilities, rather than outright relocation of already existing facilities. Note that in this particular example the corresponding expansion of foreign production that would enable the rise of net imports of the country considered need not be due to FDI from the importing, e.g. EU, country, but could equally come as a result of foreign *domestic* investment (e.g. Chinese investment in new Chinese factories).

At this stage it seems appropriate to give a brief overview of developments in the trade of manufactured goods in Europe over the period which will be analysed in the empirical part. This will also give some first hints about what modelling approach might best be suited for the problem at hand.

European manufacturing trade patterns

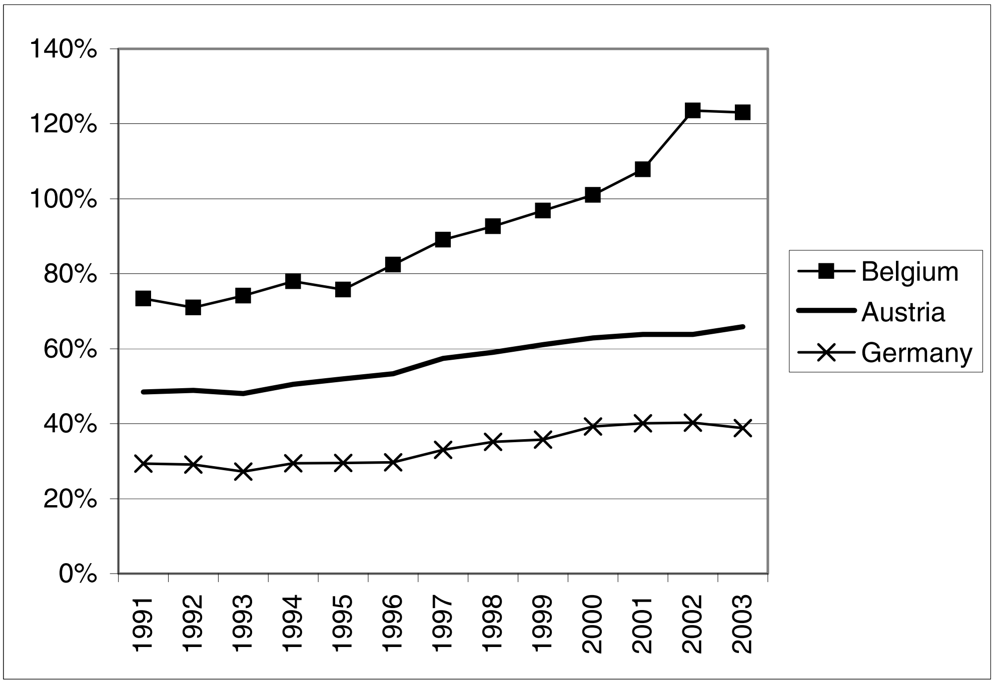
Over the 1991-2003 period, gross import penetration, defined as imports divided by domestic consumption, i.e. imports divided by output minus net exports, has increased markedly in all European countries. This applies to manufacturing as a whole as well as to energy-intensive industries. Trade intensity, defined as exports plus imports divided by output also increased markedly for both manufacturing as a whole and for energy-intensive industries over the period. There are several reasons for this and it is not the purpose of the current study to address them in any detail. Suffice it to say that significant trade liberalisation occurred both at the European and global levels during that period which in particular led to a rise in intra-industry trade. The European single market came into being from 1993, resulting in the abolition of the few remaining trade barriers between the then 12 members of the European Community, joined by Austria, Sweden and Finland in 1995. To some extent the introduction of the Euro from 1999 may have further contributed to trade integration among its participants. In parallel a general global process of trade liberalisation took place in the context of WTO agreements. The evolution of trade intensity for manufacturing goods is illustrated in graph 1 for three selected EU countries. The corresponding gross import penetrations, also for manufacturing as a whole, are shown in graph 2.

Graph 1 – Trade intensity in manufacturing (exports plus imports as % of domestic consumption) for Belgium, Austria and Germany, 1991-2003



Source: OECD STAN and own calculations

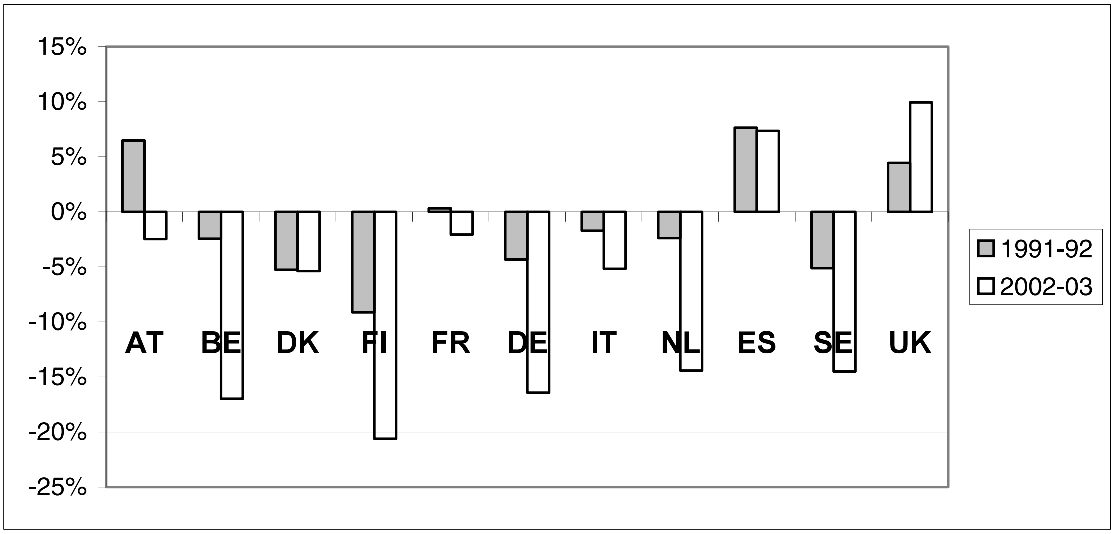
Graph 2 – Gross import penetration in manufacturing (imports as % of domestic consumption) for Belgium, Austria and Germany, 1991-2003



Source: OECD STAN and own calculations

Basing an analysis on graph 2 alone might lead us to conclude that leakage is increasing. However graph 1 indicates that overall trade intensity has increased as well, so the obvious question is how exports have evolved in comparison with imports, and hence how the net trade positions have evolved. It is common in such a case to use trade balances, possibly by industry or commodity group. However since the goal is to assess leakage it makes sense to define a net indicator with reference to domestic consumption. Therefore the choice here is to look at so-called net import penetration, which is defined as imports minus exports, divided by domestic consumption. This is illustrated in graph 3, which shows the two-year averages for 1991-92 and 2002-03 of net import penetration for 11 EU countries, among which the 6 ETR countries. What is immediately striking is that net import penetration has decreased significantly in most Western European countries. The main exception is the UK, where the opposite happened, whereas net import penetration was essentially unchanged in Spain and in Denmark. On the other hand net import penetration in Germany, the Netherlands, Sweden and Finland, all ETR countries, decreased strongly over the period. For all four countries net import penetration was negative at the beginning of the period, i.e. all four countries were already net exporters of manufactured goods at that time, and even more so by the end of the period. These shifts also do not look smaller than those experienced in non-ETR countries such as France, Italy, Austria or Belgium, in fact the opposite appears to be the case. In other words there appears to be no solid initial evidence of increased leakage from ETR countries in manufacturing as a whole.

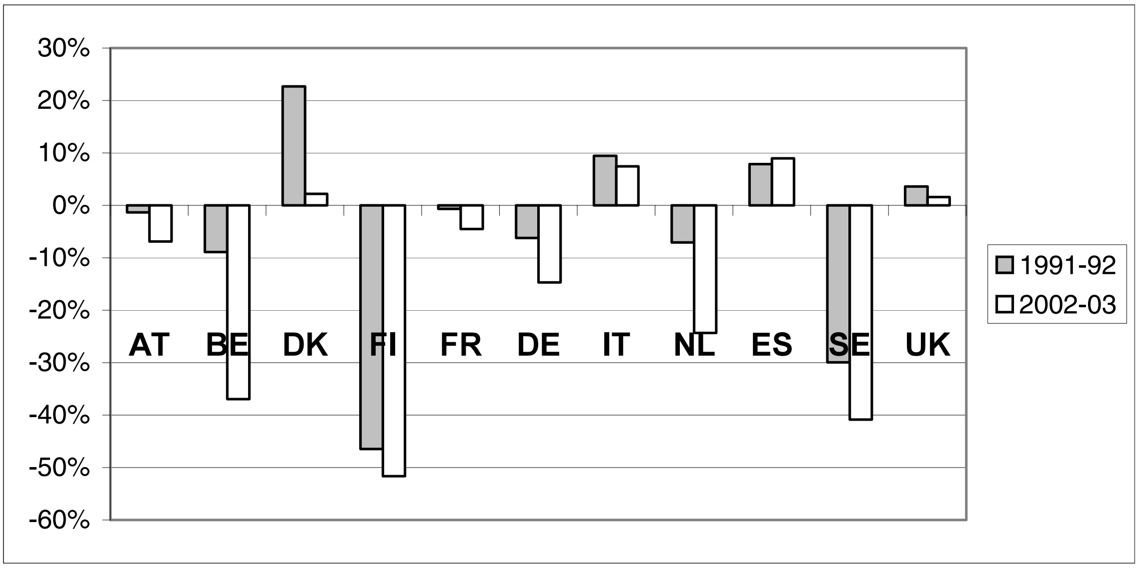
Graph 3 – Net import penetration in manufacturing (imports minus exports as % of domestic consumption) for selected EU countries, 1991-92 vs. 2002-03



Source: OECD STAN and own calculations

Is the picture any different if we look only at energy-intensive industries? After all, it is those industries that should be most sensitive to environmental tax reform. For this purpose, energy-intensive industries are taken as the aggregate of paper and paper products (NACE 21 or equivalent), chemicals and chemical products (NACE 24 or equivalent), non-metallic minerals (NACE 26 or equivalent) and basic metals (NACE 27 or equivalent). The resulting net import penetrations, also for the averages of 1991-92 and for 2002-03, are shown in graph 4. The fourth country from the left-hand side in the graph is Finland. The second country from the right-hand side in the graph is Sweden.

Graph 4 – Net import penetration in energy-intensive manufacturing industries (imports minus exports as % of domestic consumption) for selected EU countries, 1991-92 vs. 2002-03



Source: OECD STAN and own calculations

As we can see, the picture is similar to that shown in graph 3 in relation to manufacturing as a whole. Here Denmark exhibits a clear decline in net import penetration (as opposed to no significant change in graph 3), while the UK exhibits a small decrease in net import penetration. On the other hand net import penetration is clearly on the decrease in all countries except Spain, and a fortiori in the other ETR countries, namely Finland, Sweden, the Netherlands and Germany.

The very different picture emerging from net import penetration as opposed to standard import penetration seems to suggest that net import penetration is indeed an interesting and relevant indicator. This will be discussed in detail in the next section. To conclude this section it is appropriate to mention the rise of China on the world market for basic manufactured goods. In the early 1990s Chinese manufacturing could, with a few exceptions, be practically ignored as a factor in European trade flows. By the end of the period this had changed quite markedly. Also, while average Chinese manufacturing wages rose strongly over the period, they nevertheless remained extremely low by European standards right up to the end of the period. Foreign direct investment from OECD countries into China, as well as Chinese domestic investment, both skyrocketed over the period, leading to a large export potential of certain manufactured goods to world markets, including European Union countries. This was clearly reflected in the rising share of Chinese goods in European imports especially in many low value added products. It seems therefore compelling to include China as a partner country in this analysis.

Developing an economic criterion to detect carbon leakage

The scope of this study is comparatively limited in the sense that actual carbon leakage is not assessed. The reason for this simplification is due to the difficulty of obtaining comparable and reliable data on carbon-intensity: one would need carbon intensity data at the industry level not only for the selected European countries but also for all their major trading partners, e.g. the United States, Japan, China. In fact one would need estimates of the "carbon content" of bilateral trade flows as well, as traded goods may differ from produced goods from the same industry. However the indirect economic approach proposed in this paper does yield interesting results and is appropriate at least as a partial approach to the problem. In order to illustrate, one may come back to the example detailed in table 1 and add to it a further indicator: net imports divided by domestic consumption, as shown in table 2.

Table 2 – Economic view of carbon leakage

Domestic production	Net Imports	Domestic consumption	Total carbon emissions	Leakage	Total carbon intensity	Net Imports / consumption
1000	200	1200	2600	Starting point	2.167	17%
800	400	1200	2800	Absolute leakage	2.333	33%
800	360	1160	2680	Absolute leakage	2.310	31%
800	300	1100	2500	Relative Leakage	2.273	27%
1100	100	1200	2500	No leakage	2.083	8%

Source: own calculations

As we can see from table 2, net imports divided by consumption is 17% in the starting point scenario, and higher in every other case except the last scenario which is a case in which there is no carbon leakage (neither absolute nor relative). The obvious question now – given that this is based on a very specific example – is whether this is always the case, i.e. whether net imports divided by consumption is in a one-to-one relationship with relative carbon leakage as above, or if not, to what extent this purely economic indicator might be a good proxy for carbon leakage in an econometric context. As was mentioned in the description of table 1, the examples shown so far assumed that there were no exports from the home country, so that imports are equal to net imports. Obviously one must allow for the presence of exports in any proper theoretical approach, and this is done in what follows, however this raises the issue of which indicator might be the best candidate for assessing leakage, standard import penetration, net import penetration or possibly another indicator. For a number of reasons, notably in light of the empirical elements shown in the last section, it seems that net import penetration should be more suitable, so we will proceed with net import penetration and analyse its strengths and weaknesses as an indicator for leakage.

It can be shown that the two conditions (relative carbon leakage and net import penetration) are equivalent provided certain key conditions are met. The proof is as follows.

Assume that foreign carbon intensity is higher than home carbon intensity. Without loss of generality one may normalise home carbon intensity to unity. Foreign carbon intensity is written as α, with $\alpha>1$. We will of course allow the home country to have exports. However in order to facilitate the mathematical derivations shown below, we will also assume that the home country's net imports are a fixed proportion of the country's imports in both periods. We will come back to this assumption later in this section.

The economic leakage condition under the given assumptions is:

$$EL = \frac{NI_2}{P_2 + NI_2} - \frac{NI_1}{P_1 + NI_1} = NIP_2 - NIP_1 > 0 \quad (1)$$

Where NI denotes net imports, P denotes domestic production and NIP denotes net import penetration, by definition equal to net imports divided by domestic consumption, itself equal by definition to domestic production plus net imports as shown. The indices 1 and 2 denote, respectively, the first and second periods under consideration, the idea being, as with the examples in table 1, that an environmental tax reform, and possibly other developments such as relative shifts in international price differentials, might have happened between the two periods.

The relative carbon leakage condition may be defined as follows:

$$RCL = \frac{P_2 + \alpha I_2}{P_2 + NI_2} - \frac{P_1 + \alpha I_1}{P_1 + NI_1} > 0 \quad (2)$$

Where, for each term, one finds total carbon emissions[2] as the numerator divided by domestic consumption. We will come back to this definition later in this section. For now suffice it to say that the choice of (2) is partly a matter of mathematical convenience, as the denominator is the same as the one used in the economic leakage condition, and partly the result of an intuition that what matters is the carbon intensity of domestic consumption. As explained earlier, we assume that there are exports from the home country but that net imports are a fixed proportion of imports as shown in (3).

$$NI_r = \frac{I_r}{\beta}, \beta > 1, r = 1,2 \tag{3}$$

Thus (2) is equivalent to the following:

$$RCL = \frac{P_2}{P_2 + NI_2} + \alpha\beta \frac{NI_2}{P_2 + NI_2} - \frac{P_1}{P_1 + NI_1} - \alpha\beta \frac{NI_1}{P_1 + NI_1} > 0 \tag{4}$$

And, most importantly, the first and third terms in (4) can be expressed, respectively, as one minus the import penetration in period 1 and in period 2. As a result, (4) simplifies to the following:

$$RCL = (\alpha\beta - 1) \cdot NIP_2 - (\alpha\beta - 1) \cdot NIP_1 > 0 \tag{5}$$

Thanks to our assumptions that α>1 and β>1 we find that (αβ-1)>0. If in addition we assume that import penetration is positive in both periods we find the following:

$$(\alpha\beta - 1) \cdot NIP_2 - (\alpha\beta - 1) \cdot NIP_1 > 0 \Leftrightarrow NIP_2 - NIP_1 > 0 \tag{6}$$

and

$$(\alpha\beta - 1) \cdot NIP_2 - (\alpha\beta - 1) \cdot NIP_1 < 0 \Leftrightarrow NIP_2 - NIP_1 < 0 \tag{7}$$

In other terms, given our assumptions, we find that the economic leakage condition and the relative carbon leakage condition are equivalent, provided that the ratio of foreign to home carbon intensities is constant and above 1 between the two periods[3] and that the ratio of net imports to imports of the home country is constant.

Of course the assumptions made are not trivial, in particular if one considers developments over relatively long time periods. Nevertheless this result is an interesting one, as it enables us to assess the more stringent criterion of relative carbon leakage, rather than just absolute carbon leakage. In light of this it seems that net import penetration is indeed a useful indicator for assessing the issue of carbon leakage.

However one assumption seems rather problematic, namely to assume that the ratio between net imports and imports is a constant, i.e. that imports and exports must grow at the same rate. Empirically speaking this will generally not be the case, so the question is what a deviation from that assumption may mean for the relationship between the EL and RCL criteria. Numerical simulations suggest that if β decreases, i.e. if net imports grow more than imports, in other words if the trade balance worsens, then the EL criterion will in some cases flag cases of leakage when in fact there is no relative carbon leakage, while the opposite may happen if the trade balance improves. Clearly this is rather problematic for practical applications.

[2] We consider here only those emissions that are related to the home country's consumption. We do not take into consideration foreign production destined for foreign consumption.
[3] As an aside one may note that if the ratio of carbon intensities is reversed, i.e. if the home country is more carbon-intensive, then the criteria produce exactly opposite results: RCL>0 is then equivalent to EL<0.

One further caveat should be mentioned. As we saw in the empirical section, there are of course countries that are net exporters (net imports are negative). What are the consequences, if any, on our results? It can be easily shown from the equations used above that if the home country is a net exporter in both periods then the results still hold, except that the sign of the EL criterion should be inverted if using net imports, or alternatively the criterion will hold as it is if net exports is used instead of net imports. There is however a potential problem if a country switches from being a net importer to being a net exporter or vice versa from one period to the other. As we will see in the empirical section this sometimes arises. Is there a solution to these two problems?

Intuitively we had a problem from the very beginning because of the use of domestic consumption as the denominator for the measure of overall carbon intensity. This measure becomes especially problematic if the home country switches from being a net importer to being a net exporter. When this happens, if domestic production is held constant, domestic consumption falls, and in certain specific cases this fall more than compensates for the fact that imports, the production of which is more carbon-intensive, have also decreased. Since domestic production was held constant, home and foreign (export-oriented) production put together have fallen, total emissions have fallen, and, worst of all, the average carbon content of home and foreign production put together has also fallen, but this is not reflected in the measure of carbon intensity that has been used as it takes domestic consumption as its base. In light of this, one may modify the criteria developed thus far, and define the new RCL as the following:

$$RCL^* = \frac{P_2 + \alpha I_2}{P_2 + I_2} - \frac{P_1 + \alpha I_1}{P_1 + I_1} > 0 \qquad (8)$$

With this new definition the denominator is total production (though again excluding foreign production destined for foreign consumption). However it is clear that we will not be able to link this criterion as previously with net import penetration. As for standard import penetration, i.e. imports divided by domestic consumption, it is equally unsuited as it has the same denominator as net import penetration. The solution lies therefore in creating a new indicator, which one may choose to call import-activity ratio, IAR. It is defined as follows:

$$IAR_r = \frac{I_r}{P_r + I_r}, r = 1,2 \qquad (9)$$

This indicator is neither net import penetration nor standard import penetration which both use domestic consumption as the denominator, but a hybrid indicator which uses domestic production plus imports as the denominator. This is of course mathematically very convenient. Furthermore this new indicator has the advantage of being always positive, thus bypassing problems of changes in sign.

Using this new indicator we define a new economic leakage criterion as follows:

$$EL^* = \frac{I_2}{P_2 + I_2} - \frac{I_1}{P_1 + I_1} = IAR_2 - IAR_1 > 0 \qquad (10)$$

Similarly to our earlier derivations it is easy to see that (8) can be rewritten as:

$$RCL^* = (1 - IAR_2) + \alpha IAR_2 - (1 - IAR_1) - \alpha IAR_1 = (\alpha - 1)IAR_2 - (\alpha - 1)IAR_1 > 0 \qquad (11)$$

As previously, assuming $\alpha > 1$ and constant, it is immediately clear that:

$$EL^* > 0 \Leftrightarrow RCL^* > 0 \qquad (12)$$

and that

$$EL^* < 0 \Leftrightarrow RCL^* < 0 \qquad (13)$$

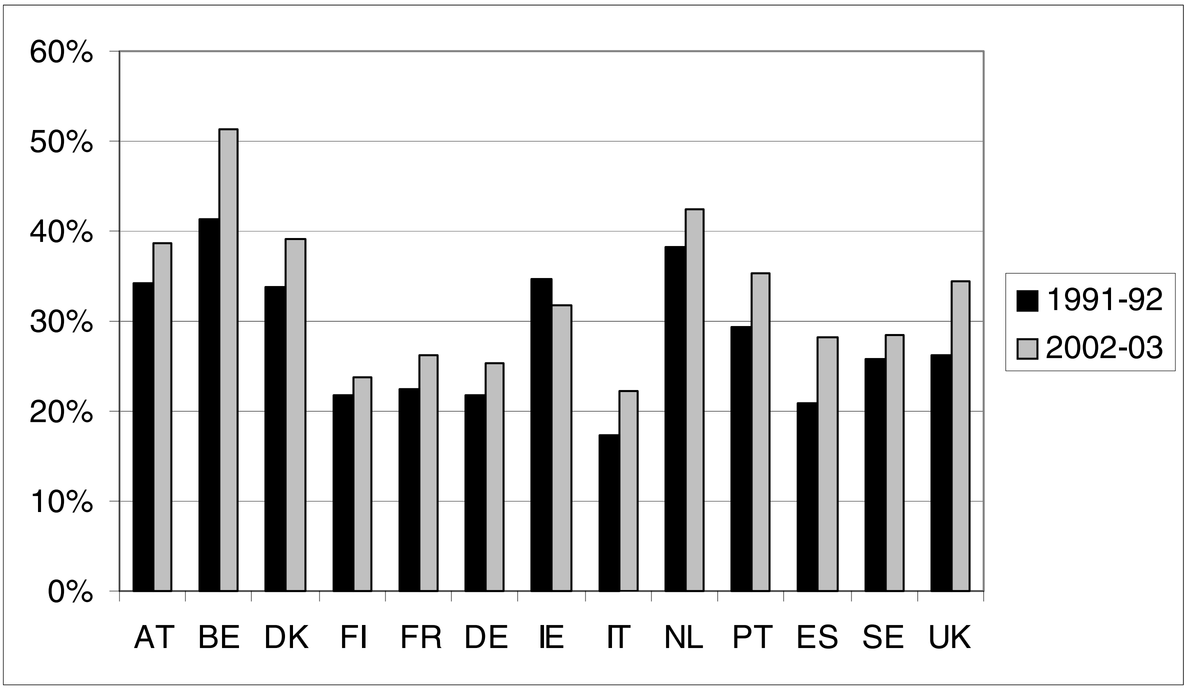
We now have a criterion for detecting relative carbon leakage which is robust to changes in the ratio between imports and exports as well as to changes in the sign of the trade balance. The other major conclusion from this section is that neither import penetration nor net import penetration are suitable for detecting carbon leakage.

The only problem, which has no easy solution, lies in changes in the value of α. This would require a separate research effort. Other issues also worthy of further investigation would be the links with absolute carbon leakage, and whether relatively simple economic proxies could be found for detecting its occurrence.

Import-activity ratio in Western Europe

Now that we have found a suitable indicator it is interesting to look at its levels and evolution in the countries that interest us. This is shown in graph 5.

Graph 5 – Import-activity ratio in manufacturing (imports divided by output plus imports), selected EU countries, 1991-2003

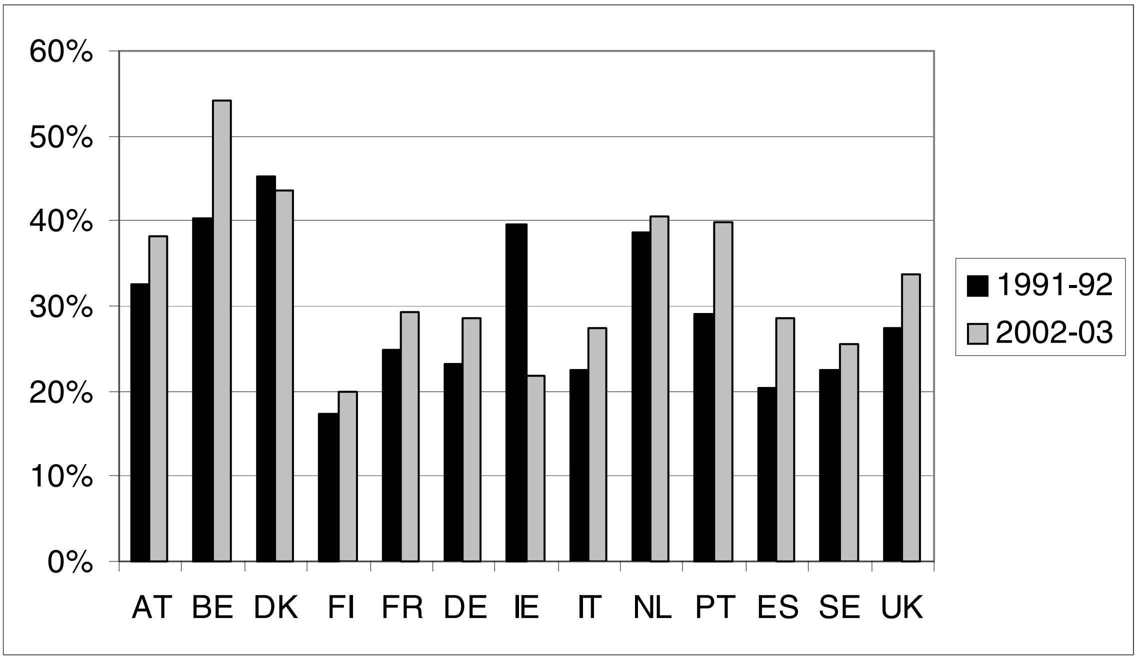


Source: OECD STAN and own calculations

As one can see, the import-activity ratio (IAR) has increased in all selected countries except Ireland over the period, with increases particularly strong in Belgium and the UK, but with more modest increases in Finland and Sweden. As for levels, IAR is high (taking 30% as a cut-off point) at the end of the period in Austria, Belgium, Denmark, Ireland, the Netherlands, Portugal and the UK, and low in Finland, France, Germany, Italy, Spain and Sweden. In terms of what we know about environmental tax reform it seems that neither the end-of-period levels nor the increases over the period correlate particularly well with ETR. On the other hand the fact that IAR has increased in almost all countries is obviously a reflection of the increased trade integration that has happened within the European Union, as well as the increased trade integration that has occurred at the global level (as an aside, IAR also increased in the USA, Japan and South Korea over the same period). It is important to understand that this evolution is driven especially by intra-industry trade, which explains why trade intensity and exports have also increased in most countries over the same period. Nevertheless, this increased trade integration does equate with economic leakage.

We now turn to IAR in the case of the energy-intensive industries. Will the pattern be any different than for manufacturing as a whole? This is shown in graph 6.

Graph 6 – Import-activity ratio in energy-intensive industries (imports divided by output plus imports), selected EU countries, 1991-2003



Source: OECD STAN and own calculations

As we can see from graph 6 the general pattern is similar to the one observed in graph 5: IAR has increased in most countries, Ireland again being an exception. However we also find Denmark as an exception, which is interesting given that it is an ETR country. Finland, Sweden and the Netherlands, also ETR countries, show only modest increases in IAR over the period. Germany and the UK on the other hand – the two remaining ETR countries – exhibit sizeable increases in IAR. However the largest increases in IAR are found in non-ETR countries, in particular Belgium, Portugal and Spain.

An empirical model for economic leakage

One wishes to assess the following relationship:

$$IAR_{ijt} = \frac{M_{ijt}}{P_{ijt} + M_{ijt}} = F\left(ETR_{it}, INT_j; controls\right) \tag{14}$$

The left-hand side is import-activity ratio for industry j into country i in year t. This, one would like to assess, could be in part explained by the ETR variable (whether the country in question had ETR in application in year t) and, or in some combination with, the energy intensity variable (whether the industry j in question should be vulnerable due to its inherent energy intensity).

Of crucial importance are of course the control variables that should provide for the other factors that explain the evolution of IAR. As discussed earlier, European countries over the period considered (1991-2003) experienced a general rise in both imports and exports that went far beyond their GDP growth due to increased trade integration. It would therefore make sense to include export intensity (exports divided by output) as a control variable. The increasing international fragmentation of production chains raises the “import content of exports”, in other words higher exports require higher imports of intermediate goods, in particular parts and components. A description of this phenomenon and some international evidence is presented in Jones et al. (2004), some empirical evidence specific to the Euro-zone can be found in Baumann and Di Mauro (2007). In the same spirit, export intensity growth is itself a result of increased integration of production.

The second category of control variables that should be included are those that would usually explain higher imports in general, i.e. both intra-industry and inter-industry trade, namely international price differentials (as used, e.g., in Bank of England, 1999), changes in barriers to imports and home market size. The latter is a candidate due to the often verified cross-sectional relationship between the size of an economy and its openness to trade, i.e. the trade-to-GDP ratio of large economies is typically smaller than that of small economies. Barriers to imports may be measured using indices of average import tariffs. As for price differentials, they are proxied in this study by an estimate of international wage differential. Wage differential is chosen here due to data availability constraints, as price differentials, either at the final product level or at the level of input prices (e.g. energy prices) were difficult to find for all countries, industries and years, notably because of the inclusion of non-European countries as trading partners. Obviously this could be improved upon in further research. How the wage differential indicator and the import tariff indicator are constructed is discussed later in this section.

Additional control variables may also be introduced, such as country and/or industry and/or time dummy variables, e.g. in the context of a fixed effects regression. Of course if such dummy variables are introduced they may to some extent wipe out the explanatory power of properly economic variables such as home market size. That is an econometric issue.

The question now is what modelling strategy should be applied. A full 3-dimensional array of data (N countries, J industries, T years) could be used. Alternatively, two-dimensional panel data sets could be assessed separately, or be somehow joined or related to one another.

The choice made for this analysis is to enable a comparison between manufacturing as a whole as opposed to energy-intensive industries which should be more sensitive to ETR. For this purpose, energy-intensive industries are taken as the aggregate of paper and paper products (NACE 21 or equivalent), chemicals and chemical products (NACE 24 or equivalent), non-metallic minerals (NACE 26 or equivalent) and basic metals (NACE 27 or equivalent).

The data-set is thus put composed of two separate panel data sets, one for manufacturing as a whole and one for the energy-intensive industry aggregate. These two panels are then stacked into a single panel data set. The question will then be how to best model this “double panel”. Standard panel data estimation methods such as fixed effects or random effects will treat each group as a separate individual observed over the period, e.g. Austrian manufacturing will be one group, while Austrian energy-intensive industry will be a separate group. However country dummy variables are also created as an alternative specification that is less costly in terms of degrees of freedom. The energy-intensive industry dummy variable will in both cases be available to check for differences between the two panels.

The main data source used for the analysis was the OECD’s STAN database, complemented with datasets from Groningen’s Growth Development Centre (GGDC) and the KLEMS database in order to fill in missing values. In terms of country coverage, the idea is to contrast the experience of EU member states that introduced ETR as compared to EU member states that did not, over the 1991-2003 period. Due to data availability issues it was necessary to exclude Greece and Luxembourg. Thus the analysis is carried out on the remaining 13 countries that were members of the European Union at the end of the period.

The wage differential variable is constructed as the difference between the average home country wage in the industry in question and the import-weighted sum of foreign wages for the same industry. This wage differential is computed separately for each reporting country (the 13 selected EU15 member states), for each year (1991 to 2003) and for both industry aggregates (manufacturing total and energy-intensive industries). In each case one uses the imports of the reporting countries from their trade partners. Ideally one would have to consider all the countries of the world as partners, however this would have required wage data from all countries of the world on an industry-by-industry level. However if we stick to the major OECD countries we find that they account for the overwhelming share of trade in manufacturing goods for EU member states. Ultimately the following countries were included as partners: the EU15 countries themselves (minus Luxembourg and Greece), the USA, South Korea, Japan, Poland, Hungary, the Czech Republic, Slovakia and China.

$$WD_{ijt} = w_{ijt} - \frac{\sum_{p=1}^{20} w_{pjt} \cdot imp_{ipjt}}{\sum_{p=1}^{20} imp_{ipjt}} \tag{15}$$

Where i = 1, … 13 is the index for the reporting countries, p = 1, …, 20 is the index for the trade partners, j = 1, 2 is the index for the industry and t = 1991, …, 2003 is the year index.

The wage data was constructed from the KLEMS database (labour compensation divided by employment) for all OECD countries except South Korea, for which STAN data was used instead. However the KLEMS database only includes data starting from 1995 for Poland, the Czech Republic and Slovakia, so estimates were made combining STAN data (where available), wiiw industrial data and linear extrapolations in order to have a complete dataset starting from 1991 for all partner countries. Finally for China data was taken from the China Statistical Yearbook, 2005 edition, where average manufacturing wage data (in yuan, converted using official exchange rates) was used for both industry aggregates.

An alternative functional form for wage differential was also constructed in order to estimate a log-linear model, using the ratio of the domestic wage to the trade-weighted foreign wage:

$$LWD_{ijt} = \ln\left[w_{ijt} \cdot \frac{\sum_{p=1}^{20} imp_{ipjt}}{\sum_{p=1}^{20} w_{pjt} \cdot imp_{ipjt} \sum_{p=1}^{20} imp_{ipjt}} \right] \tag{16}$$

An index for import tariff protection was also constructed in order to serve as a control variable. For this purpose, average applied MFN tariff rates of the European Union were obtained from UNCTAD's TRAINS database and weighted by the corresponding imports into the European Union for each year.

Estimation results

After some estimation attempts with purely linear specifications it was decided to switch to the more standard log-linear approach. Therefore the following empirical log-linear model was estimated:

$$\ln(IAR) = \alpha + \beta_1 \ln(EXP) + \beta_2 LWD + \beta_3 \ln(TAR) + \beta_4 \ln(SIZE) + \beta_4 ETR + \beta_5 ESM \tag{17}$$

Where IAR is import-activity ratio, EXP is export intensity (exports divided by output), LWD is the wage differential variable as defined in (16), TAR is the tariff index, SIZE is a measure of home market size, taken here as total manufacturing output, ETR is a dummy variable equal to 1 for those countries and in those years where ETR was in place, and ESM is a dummy variable for the European Single Market, equal to 1 from 1993 for those countries that were then members of the European Community, and equal to 1 from 1995 for Austria, Finland and Sweden.

This empirical model was estimated on the "double panel" described earlier, i.e. the stacking of two balanced panel data sets covering 13 countries over 13 years, the first 169 rows in the data set covering manufacturing and the subsequent 169 rows covering the energy-intensive industry aggregate.

The model was first estimated using fixed effects. The estimates were made using STATA 9.1, using the XTREG command. In that context the wage differential variable wasn't found to be significant.

However export intensity and home market size were both found to be significant and of the expected signs: positive for export intensity (more exports require more imports) and negative for market size (larger economies are less trade-intensive). The tariff index was also found to be significant and of the expected negative sign (lower tariffs lead to higher imports). However the ETR dummy variable was found to be clearly not significant.

However post-estimation tests indicated the presence of both heteroskedasticity and autocorrelation[4]. For these reasons it was necessary to correct for both of these problems. This was done using STATA's XTPCSE command, which computes a Prais-Winsten regression on a panel data set with the estimation of group-specific heteroskedasticity and auto-correlation terms. Several estimation options are available in this context, and the choice made was to use a common AR(1) term for all 26 groups and group-specific heteroskedasticity correction without contemporaneous correlation terms between groups to deal with heteroskedasticity. Finally in order to be in keeping with the initial fixed effects regression the corresponding 26 group dummy variables were introduced as additional explanatory variables (the common intercept being of course dropped to prevent multicollinearity). In this context the wage differential variable was (unsurprisingly) again found to be not significant and was thus excluded for the final estimate, the results of which are presented in table 3. The group dummy variable estimations are not shown.

Table 3 – Estimation results – Heteroskedasticity- and autocorrelation-corrected log-linear LSDV model of import-activity ratio

	COEFFICIENT	STD. ERROR	Z-STATISTIC	P-VALUE
Export intensity	0.490	0.056	8.74	0.000
Manufacturing output	-0.200	0.053	-3.76	0.000
Tariff index	-0.139	0.028	-4.93	0.000
ETR dummy v.	0.009	0.010	0.91	0.364
Single market dummy v.	-0.036	0.009	-3.87	0.000
Rho (AR coef.)	0.457			

Source: own estimations

As can be seen from the estimation results, the three control variables, export intensity, manufacturing output (the size effect) and the import tariff index are significant and of the expected signs. The single market dummy variable is significant, but negative, which is of course unexpected. However this should be seen in the context of the presence of the export intensity variable which captures increased trade between EU member states and which is a much more important variable thanks to the large magnitude of its coefficient estimate. The ETR dummy variable is again found to be clearly not significant. The R-squared is very high (0.9575), as one would expect when using up so many degrees of freedom. However the goal of testing the ETR variable in an adequately controlled setting is met. Finally one may mention that the ETR variable was tested separately for the energy-intensive aggregate (same regression, with ETR=1 if and only if the observation relates to energy-intensive industry for an ETR country and year). The estimation was also not significant (p-value 0.124).

Conclusions

In this paper it was shown that the import-activity ratio – defined as imports divided by imports plus domestic production – is a suitable proxy for relative carbon leakage under certain conditions, in particular stability of the home and foreign countries' carbon intensity ratio. This indicator was then used to make an assessment of carbon leakage for 13 European Union countries over the 1991-2003 period, in particular in order to test whether the environmental tax reforms (ETR) introduced in 7 of the assessed countries had led to more leakage than in those European Union countries that had not.

The empirical findings enable the following conclusions: economic leakage has occurred in all but 1 of the 13 EU countries that were assessed during the 1991-2003 period with respect to manufacturing

[4] Using, respectively, commands xttest3 which performs a modified Wald test for group-wise heteroskedasticity and xtserial which is a test for autocorrelation within groups in a panel data set after fixed effects estimation.

as a whole and in all but 2 in the case of energy-intensive industries, the exceptions being Ireland, and Ireland and Denmark, respectively. This leakage is primarily due to increased trade integration both at the European and global levels. Environmental tax reforms introduced in certain EU countries during the 1991-2003 period have not led to higher leakage than occurred in EU countries that had not introduced ETR. This result holds both for manufacturing as a whole and for the energy-intensive industry aggregate which was used. Assuming that economic leakage adequately proxies for carbon leakage one may conclude that carbon leakage has occurred over the period in the countries mentioned, but that its extent was not significantly different in the ETR countries.

In spite of these relatively clear results it is necessary to point out a number of important caveats to the analysis made and offer, perhaps, some ideas for future improvements.

The key assumption underlying the theoretical contribution made in this paper is that the carbon intensity ratio should remain constant. This is of course not verified empirically. However a more serious empirical problem lies in the treatment given to the trade data as a whole. A substantial share of the imports of the countries assessed is intra-EU trade. In this context the assumption that the (import-weighted sum of) foreign partners are on average more carbon-intensive than the assessed country seems rather strong in particular if one considers that there are, by definition, some EU countries that have a carbon intensity (in manufacturing, respectively in the defined energy-intensive aggregate) that is above the EU average. This particular problem can only be corrected with the help of emissions data. Of course it would have been tempting to use only extra-EU trade, but this would have had the disadvantage of limiting the value of the ETR versus non-ETR country comparison. Indeed, one advantage of the current analysis was to bring together into one sample countries that operate under very similar economic conditions, e.g. common market regulations, common external tariff, but that differ from one another in terms of environmental taxation.

Beyond the issue of ETR assessment, one interesting exercise for future research could be to confront the results obtained using the simplified import-activity ratio approach with more precise assessments using emissions data. This would enable an empirical assessment of the actual limitations of such an analysis. Two other desirable improvements perhaps worth mentioning would be to assess each energy-intensive industry separately, at least at the NACE 2-digit level, at a more disaggregated level if possible, and to account for productivity levels in the construction of the wage differential indicator. As for the theoretical part, further work on possible economic criteria for absolute carbon leakage, and on links between absolute and relative carbon leakage could be undertaken.

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Environmental Tax Reforms in Europe: Stabilisation, mitigation and compensation

WP6

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Abstract

It has been suggested that carbon-energy taxes would need to be increased to a level of 20-30 euro/tonne CO_2 in 2020 in order to achieve a stabilisation target for greenhouse gas concentrations. While increases in carbon-energy taxation inevitably raise questions concerning the negative impacts on economic growth and competitiveness, the European experience shows that governments, as part of already agreed environmental tax reforms (ETR), in fact have implicit carbon-energy taxes in place with a nominal level that in many cases exceeds this level. Still, European governments have introduced exemptions, especially for energy-intensive industries, and so to some extent, for the biggest polluters, the incentives to improve energy efficiency and shift towards low-carbon fuels have been weaker than the nominal rates would suggest. In view of the need to increase the real level of carbon-energy taxation, while retaining the competitiveness of the European economy, this paper addresses the member state approaches for mitigation and compensation applied to energy-intensive industries in the ETR countries.

From a sectoral perspective, the burden of ETR for specific energy-intensive industries remains modest. Company managers in energy-intensive industries may have failed to appreciate the benefits of improvements in energy efficiency as well as the positive impacts of revenue recycling. Instead, they may have focused more on the gross burden of ETR, which, unadjusted, has amounted to a maximum of 5 per cent of gross operating surplus. Still, where revenue recycling via reductions in employers' social security contributions has been employed to compensate for competitiveness effects, the burden is significantly lower; for the sectors of cement and glass it amounts to less than 1 per cent of the gross operating surplus, while for ferrous and non-ferrous metals in some cases it appears to have reached 2 per cent of gross operating surplus. As technologies are available which allow for significant reductions in the consumption of fuel and carbon emissions in the most energy-intensive sectors, the cement and steel sectors, a gradual phase-out of exemptions would not necessarily endanger the economic activities of these sectors. A revenue-neutral shift of taxation from labour to carbon-energy primarily benefits labour-intensive industries, but where the transport sector is included in the tax-base shift, the additional revenue which accrues from this source allows for higher levels of compensation for the energy-intensive industries.

1 Introduction

A shift of the tax burden away from labour and towards a carbon-energy tax base will inevitably favour those industries that are labour intensive and to some extent penalise industries that are energy and carbon intensive. So far, the purpose of *mitigation* has primarily been to avoid undesired impacts on the competitiveness of energy-intensive industries, which are believed to be the most vulnerable to ETR and to energy price increases. Effects that are undesirable relate in particular to closure or dislocation of industries so that the response to carbon-energy taxation becomes one of carbon leakage rather than one of energy efficiency and fuel shifting. Other undesired effects include discrepancies in mitigation approaches among EU member states, giving rise to an uneven playing field with regard to competition within industrial sectors.

The aim of this paper is to provide a more detailed overview of the approaches adopted by member states to mitigate and compensate the potential competitiveness effects of environmental tax reforms, comparing differences and similarities. The insights gained are used to provide a more forward-oriented discussion of the options for a more level playing field and best practice across the EU as regards mitigation and compensation practices in relation to the competitiveness effects of carbon-energy taxation. While the guidelines for state aid in the environmental sector at present provide a framework for exemptions, the aim is to take a broader perspective in view of the findings of the COMETR project. The detailed data on energy consumption, carbon-energy taxation and economic performance allows for a more detailed analysis of the relative costs and gains of ETR for the various industrial sectors, which will be explored here in view of the insights and findings of the various COMETR work packages.

It has been suggested that in order to attain a stabilisation target of 450-550 ppm for GHG concentration in the atmosphere, and to curb increases in the average global temperature to 2 degrees, the cost of carbon should - for all sources – start from a level of 10 euro/tonne in 2010 to 20-30 euro/tonne in 2020, e.g. an annual increase of 1-2 euro/tonne (Barker, 2007). Although such tax rates would need to apply globally they are not, in fact, out of line with the tax rates that currently apply for industrial processes in the seven EU member states (Denmark, Finland, Germany, Netherlands, Slovenia, Sweden and UK) analysed in this study. Here the nominal tax rates are in many cases above 20-30 euro/tonne CO_2, but the exemptions in many instances lead to effective tax rates which are well below, or only a fraction of, the recommended future levels; an increase in tax rates would, therefore, pose a significant challenge for certain exempted sectors.

The seven member states that have introduced ETR have implemented quite different mitigation measures. The differences in scope are interesting to study and contrast as they reflect somewhat different strategies for mitigating competitiveness concerns. In recent years, member states have increasingly been constrained by the EU regulations on state aid in the environmental sector. Under these regulations the *exemptions* from environmental taxes are regarded, functionally, as a potential form of state aid and have become subject to a range of restrictions and procedures. Although there are significant differences in member state approaches to ETR and ETR mitigation, under EU law a common legal framework has gradually emerged. This legal framework constrains the options of member states when considering mitigation approaches.

We will not here set out on a legal analysis of the state aid rules, as our research interest lies in the policy analysis and evaluation of experiences attained in the member states with different approaches to mitigation. Some of the initial mitigation practices, introduced in the early 1990s, would probably not qualify for approval under the present state aid regulations, yet they might warrant interest from the perspective of obtaining CO_2 reductions while safeguarding competitiveness. In the following sections, an overview of the approaches adopted for mitigation and compensation in the seven member states is provided. Subsequently, the relative implications of each of these approaches for industrial sector earnings are assessed.

2 Member state approaches to mitigation and compensation

OECD (2001) distinguishes between ex-ante mitigation and ex-post compensation measures respectively; while ex-ante measures provide for reductions of tax rates or modifications of tax bases, ex-post measures are outside the realm of the taxes, as such. Ex-post compensation measures include revenue recycling, subsidies and border tax adjustments. Environmental tax reform tax-base shifts should preferably remain revenue-neutral to avoid negative effects on the business cycle, but revenue-neutrality can be obtained via various routes, e.g. involving a lowering of social security contributions, income taxes or some combination of the two.[1]

The OECD states that 'Mitigation measures reduce the environmental effectiveness of the tax by cancelling out some of the incentives to change consumption and investment behaviour' (OECD, 2001:29). This statement is difficult to question, but it should be noted that the loss of environmental effectiveness is conditional upon the insertion of the term '*financial*' before the word 'incentives', as in some cases other incentives may be embedded in the mitigation measures (e.g. agreements). Where mitigation alters the tax rates or tax bases, such ex-ante measures will distort the effective reduction of emissions, whereas when ex-post compensation provides additional incentives, the environmental results may still be attained; although the claim for optimality may be difficult to justify. Voluntary sectoral agreements, for instance, rely on a presumption for a collective norm, which will commit companies to deliver a similar amount of CO_2 reduction as would follow from purely economic incentives. In a similar vein the recycling of tax revenue, e.g. for targeted subsidies to energy efficiency measures, may help lower the marginal-cost curve and hence mitigate the need for more substantive tax rates.

In the following sections we provide an overview of the mitigation and compensation practices in member states, whereas for a full overview of ETR reforms the interested reader is referred to Speck (2006).

2.1 Ex-ante measures: choice of tax base and reductions in tax rates

Sweden

Sweden's 1989 environmental tax reform transformed the existing practice of energy taxation on industry to a combined energy and CO_2 tax base, which resulted in a level of carbon-energy taxation which by international standards was exceptionally high. In the years 1991 and 1992, energy-intensive industries were charged effective carbon-energy tax rates of 70-80 Euro per tonne of CO_2 or 3-4 Euro per GJ. The tax rates for industries were established to be similar to those for households. Overall the initial tax rates corresponded to the European Commission's 1990 proposal for a carbon-energy tax of 10 US$ per barrel of oil.

The initial scheme was soon overturned by competitiveness concerns and the CO_2 tax rate for all industrial sectors was reduced to 25 per cent of the initial level, while the traditional energy taxation on industry that had been in place since 1974 was abolished. In 2006, industry paid 21 per cent of the CO_2 tax rate for households. From 1993 and until the implementation of the Energy Taxation Directive, Swedish industry was also exempt from electricity taxation.

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[1] Social security contributions are in some countries regarded as charges rather than as taxes; however, for the sake of simplicity we will discuss all compulsory payments as part of the overall tax burden on labour.

The initial scheme, as well as its successor, allowed a cap on carbon-energy taxation sectors where energy taxation exceeded 1.7 per cent of the value of product sales[2]. The mitigation approach was to some extent discretionary in that companies applied individually in order to obtain the cap on energy taxation. Among the concerns indicated by a government investigator, already in 1991 (SOU 1991:90) as Sweden was negotiating its EU membership, was the possible conflict of the cap with the state aid rules of the European Union.

Nevertheless the exemption mechanism has been continued. The cap was lowered for a while to a level where the tax burden exceeded 1.2 per cent of product sales value, and substantial reductions (75%) were available already at a point where 0.8 per cent was exceeded (NMR, 1994: 95). From 2006, the 0.8 per cent offers a threshold rather than a cap and provides the possibility for reduced tax rates only, not a complete exemption; and, furthermore, the tax reductions are limited to coal and gas. The reduced rates are only about 15 per cent (1/6) of the nominal rates for industry and are somewhat similar to the EU minimum rates.

About 50-60 energy-intensive companies are believed to benefit from the threshold for reduced CO_2-taxation (NVV, 1997:50; NMR, 2002:100).

In contrast to other EU member states, a requirement for agreements or voluntary measures to reduce CO_2 emissions in order to benefit from the lower tax rates above the threshold has not been in place (but has been introduced from 2006).

Finland

Finland was the first country to introduce a CO_2 tax; one which took effect already from 1990. The Finnish CO_2 tax was introduced with uniform tax rates for all industrial sectors and it applies according to the carbon content of fuels. One reason for the application of a uniform CO_2 tax rate which often is mentioned is the prevalence of hydropower and nuclear power in Finland. Still, fossil fuels contribute more than 60 per cent to energy supply, so the CO_2 tax has more impact than in Sweden; although for industry the effective tax payments are comparable.

No special exemption mechanism for energy-intensive industries accompanied the initial Finnish CO_2 tax scheme. The reason for the absence of mitigation measures seems to have been the relatively modest level of the initial CO_2 tax. From 1993, however, the level of the CO_2 tax has been gradually increased, and has become comparable to recent Swedish levels of carbon-energy taxation for industries.

In 1998 a mechanism to relieve energy-intensive industries was introduced. This mechanism involves a threshold which allows for a substantial reduction in CO_2 taxation (85 per cent) for energy-intensive industries where the carbon-energy taxation burden exceeds 3.7 per cent of value added. This tax relief is mainly to the benefit of the pulp and paper industry, where about 10-12 companies are reimbursed (NMR, 2002: 64).

A pioneering element of the early carbon-energy taxation scheme in Finland was the principle of fuel-input taxation for electricity production, rather than a conventional end-user tax. As the tax scheme applied a uniform tax rate for imported electricity, however, it was found to be in conflict with EU competition rules (see Outokompu Oy case; C-213/96); and, in 1997, Finland changed the tax base and an end-user electricity tax has been applied ever since. The end-user electricity tax is

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[2] In 1990 the cap reduced overall carbon-energy taxation on the manufacturing industry by 10-15 per cent.

unable to discriminate according to carbon emission and so the environmental effectiveness of the energy taxation scheme has, as regards electricity, lost its original precision.

Denmark

The mitigation schemes in Sweden and Finland are relatively simple and involve only few companies; in contrast the scheme which has been introduced in Denmark is comprehensive and complex. Whereas the CO_2 taxes in Sweden and Finland altered the tax bases of existing industrial energy taxes, no taxation on industrial energy consumption was in place in Denmark prior to introduction of the CO_2 tax in 1992. The novelty of taxation on industrial energy consumption, as well as the associated political negotiations, may help explain why competitiveness concerns were more outspoken as well as why mitigation measures became more prevalent.

For industry, the standard Danish CO_2 tax rate of Euro 12/tonne for fuels is about half of the reduced Swedish tax rate for CO_2 from fuels. In the first phase in Denmark, from 1992-95, there was in fact the possibility for a further 50 per cent refund of the CO_2 tax for all sectors. In addition, tax payments exceeding a threshold of 3 per cent of net sales value were reduced by 90 per cent. As a result the effective CO_2 tax rate for heavy industry was 5 per cent of the nominal rate.

In the second phase, from 1996, the mitigation measures were constrained. The new system introduced three different tax rates for standard industrial processes, heavy industry processes and heating purposes, respectively. The standard rate continued at Euro 12/tonne CO_2 and reductions were phased out, except for industries that would commit themselves to energy efficiency measures by means of binding agreements. However, heavy industry with agreements continued to benefit from arrangements that allowed them to lower their tax rate to 3 per cent of the standard rate, which must be regarded as a rather favourable reduction even compared with the initial system. It is estimated that about 100 companies benefit from the reduced rates for heavy industries, and that these companies are responsible for more than half of industrial sector emissions of CO_2.

Only the tax rate for industrial space heating is similar to tax rates paid by households (about Euro 80/tonne CO_2). An end-user CO_2 tax on electricity reflects the average CO_2 content of the Danish energy supply system and applies equally to households and industry with a rate of 1.2 eurocent/kWh. This is similar to the Dutch approach but higher than in the other Nordic countries, reflecting the higher carbon content in Danish electricity generation.

A particular feature of the Danish mitigation approach has been the recycling of revenues for energy efficiency purposes. 20 per cent of the revenue generated by the CO_2 tax on industries has been recycled for energy efficiency measures (while the remaining revenue has been used mainly to reduce employers' social security contributions). Annually from 1996-2001 more than one thousand industries received energy efficiency subsidies on the basis of the CO_2 tax revenues. These generally required co-financing and an internal rate of return allowing for a 4-year depreciation period.

Netherlands

The Netherlands first hesitated to introduce an environmental tax reform, and for several years the regulatory approach to energy-intensive companies was agreement to binding long-term sectoral agreements between the government and energy-intensive sectors.

In 1996 a 'small-users' tax' was implemented and instituted a carbon-energy tax scheme along the lines of the European Commission's proposal for the EU as a whole. The Dutch small users' tax combined with two existing taxes to increase energy taxation for the latter to constitute an important source of revenue.

The small-users' tax applies to a range of energy products, but tax rates for two important energy products were mitigated. The tax scheme provided a cap for all energy-intensive industries from taxes above certain thresholds (initially 170,000 m3 natural gas or 50,000 kWh electricity), implying lenient treatment of energy-intensive industries. These thresholds were adjusted several times and are now much higher, 1 million m3 for gas and 10 million kWh for electricity.

Most companies were affected by the small-users' tax, but even with the high caps about 60 per cent of industrial energy consumption of gas and electricity was subject to the reductions.

From 2001, a zero rate has no longer been available above the thresholds, but tax rates are reduced according to a scheme that differentiates among different consumption level groups. From 2004 and following the implementation of the Energy Taxation Directive, the energy-intensive industries are, via the reductions, effectively liable to the European minimum rates for energy products for consumption above the thresholds.

For smaller users the tax rates in the Netherlands are generally modest compared with the Nordic countries; the level for natural gas (1-10 million m3) is about half the level in Denmark. For electricity, however, the tax rates in Netherlands are comparable to the Danish rates for industry, and are significantly higher than those in Finland and Sweden.

Slovenia

The Slovenian CO_2 tax, which was introduced in 1997, supplemented the former *ad-valorem* energy taxation of liquid fuels. It was extended in 1999 and 2000 also to include excise duties for transport fuels and natural gas. More than 50 per cent of Slovenia's electricity is produced from hydro or nuclear units, though, and electricity has not been subject to CO_2 taxation *per se*. However, from 1992-1999 electricity was subject to a 5 per cent non-deductible sales tax that also applied to industry (Ministry of Environment, 1997: 132), while from 2007 the EU minimum rate has been introduced.

There have been a complex range of reductions available from the CO_2 tax. Certain energy-intensive industries, including power plants, with more than 10 tonne of annual CO_2 emissions, were allowed a basic deduction according to their baseline emissions. Coal used for power generation has been explicitly exempt. In addition, CHP units received a tax reduction, and also for district heating reductions were available. Specific companies producing heat insulation materials and transport installations for natural gas have been exempt. In total about 150 companies benefited from direct reductions; however, a broader range of companies benefit indirectly from the treatment of the electricity generators. The Slovenian government indicates in their report to the UNFCC that the value of exemptions to industry amounts to 67%, and this figure is also mentioned in an independent report (Klemenc, Merse and Tomsic, 2002). It is not clear whether this share refers to the share of electricity consumption or whether some fuels are included too.

The situation changed fundamentally when Slovenia joined the European Union in May 2004. The European Commission investigated the compatibility of the exemptions with the Energy Taxation Directive and the state aid rules. As a result the scheme was changed by 1 May 2005, and the reductions for specific companies will be phased out over a period of 5 years from that time. The reductions for power plant fuels and CHP operators remain in place, as they are in accordance with the principles of the Energy Taxation Directive. Although the Commission was not explicit in its decision, it seems that reductions for power plants are admissible because the Energy Taxation directive requires an end-user tax for electricity. According to the accession agreement, Slovenia introduced the minimum rates for electricity taxation of industries by 1 January 2007.

The nominal tax rates in Slovenia for liquid fuels are comparable to those found in other member states. Energy-intensive industries have apparently not received special mitigation treatment under Slovenia's CO_2 taxation scheme, except for a recent attempt to exempt ETS sectors. The interplay between CO_2 taxes and emissions trading is discussed further below.

Germany

Germany's Environmental Tax Reform, which was introduced in 1999, extended an earlier system of taxation of liquid energy products for industry and transport. Although its introduction was highly advertised, the tax reform merely entailed that, for electricity, the *Kohlepfennig*, which had been phased out in 1996, was to be succeeded by a new environmental electricity tax from 1999. The current tax base is not adjusted according to the carbon content of fuels, however, and it is noteworthy that coal as fuel for industrial purposes was not taxed until 2006. The main revenue seems to accrue from the transport sector rather than from industry.

While the nominal tax rates per tonne of CO_2 for liquid fuels and natural gas are comparable to those of Sweden and Finland, the reduction mechanisms for energy-intensive industries result in much lower effective tax rates for companies. In the German system there is both a cap on tax payments and a threshold for peak-adjustments above which significantly reduced rates apply.

The cap: During the first four years, from 1999-2002, the net tax rates for all manufacturing industries as well as for the agriculture, fishery and forestry sectors were set at 20 per cent of the nominal rates. From 2003 the net rates have been adjusted to 60 per cent of the nominal rates.

The peak adjustment: In addition to this cap arrangement and in order to mitigate specifically the impacts on energy-intensive industries, the German system also offers a second option, the special *'spitzen-ausgleich'* (peak adjustment) to industries that otherwise would experience a net increase in taxation when comparing the tax relief from reduced social security contributions with the increased energy tax rates. The derogation initially guaranteed a full reimbursement above a 20 per cent net tax increase, but since 2003 the reimbursement instead has been limited to 95 per cent of the full tax increase to retain a more balanced incentive for energy efficiency. The peak adjustment applies only to the energy tax increases introduced from 1999 and onwards.

The combined effects of the exemptions work out differently for different sectors. The exemption of coal is believed to have favoured the iron and steel industry, which consumes more than 80 per cent of this fuel. For the remaining industries the reduced rates do not affect the energy taxes in place before 1999, so the net effect from 2003 is believed to be a reduction of the nominal rates to approximately 60 per cent rather than 40 per cent. However, for industries that benefit from the peak adjustment arrangement the reductions are more significant, as became clear from the comparative analysis of implicit carbon-energy tax rates in WP1, cf. Speck (2006). Nevertheless, the German authorities have shown that the reduced rates are sufficient to meet the minimum rates of the EU's Energy Taxation Directive. As with Sweden and the Netherlands, the reduced rates for energy-intensive industries allow for an alignment to the minimum rates of the EU Energy Taxation Directive.

The first type of reduction (the reduced rate for all manufacturing industries, etc.) is in accordance with EU state aid regulations but is limited to a period of 10 years.

For the energy-intensive industries the second type of reduction (peak adjustment) is conditional on the fulfilment of the voluntary agreements concluded with industries which have established targets for energy efficiency. The European Commission has extended the exemptions, but has required additional targets to be established as well as a system of penalties for non-compliant parties.

The German government assesses the annual value of the 'peak adjustment' to 2 billion euro for German industry. The value of all the exemptions to industry comes to about 5.7 billion euro as compared to total ETR revenue in Germany of 18 billion euro.

UK

In the UK the Climate Change Levy (CCL) was adopted in 1999 and introduced in 2001. It applies to gas, coal, electricity and LPG for industry and commerce while households are exempted. Liquid fuels are not covered, as they are covered by the hydrocarbon oil duty. Nominal tax rates are among the lowest in the seven countries reviewed here. The CCL succeeded the fossil fuel duty for electricity. The introduction of the CCL can be regarded as an implicit ETR in so far as the revenue it brings would otherwise have required an increase in other taxes, but there was not an explicit 'tax shift' as such.

Reductions (80%) are available for energy-intensive industries, e.g. as classified under the EU's IPCC Directive. The sectors comprise cement, aluminium, ceramics, chemicals, food-drink, foundries, glass, non-ferrous metals, paper and steel and 30 smaller sectors. There is a requirement to comply with stringent energy-efficiency agreements that are negotiated with the sector associations. The results of the agreements are reviewed, and continued discounts rely on targets being achieved.

Part of the revenue (about 5%) is channelled to investments in energy efficiency via the Carbon Trust.

For electricity the CCL provides an end-user tax, but there is an exemption for 'new' renewables (wind, solar, etc, but not larger hydropower plants or waste incineration). There is also an exemption for 'good quality' CHP.

2.2 Ex-post compensation measures: revenue recycling and subsidies

In the public finance literature it has been pointed out, e.g. by Bovenberg and de Mooij (1994), that revenue-neutrality of environmental tax reform is desirable, but that it might not be sufficient if one wants to avoid negative effects. This is due to concerns about a tax interaction effect, which may arise if energy prices lead to increases in consumer prices that lower the value of after-tax income. The tax interaction effect neutralises the positive effects of environmental tax reform and may in fact turn negative in the case where the relief on income taxation is too small to offset the price increases. In the case of negative results, the energy taxes will instead have inflationary effects, as employees demand compensating wage increases. An important exception to this concern occurs, however, when revenue-recycling takes place via a lowering of employers' social security contributions.

Some observers question whether the tax interaction effect should really be a concern. First of all, the assumptions of the theoretical argument of tax interaction effects are very strict; it is assumed that the pre-existing income taxation system *a priori* minimises the excess tax burden. It also hinges on the assumption that ETR is introduced on top of a set of regulations that effectively internalises the externalities (Weinbrenner, 1996). Some authors also question the elasticities and, especially for the Nordic countries, there is evidence that for dual-earner families higher prices actually increase rather than lower labour supply.

In view of these theoretical controversies it is relevant to compare the approaches to revenue recycling employed in the various member states under scrutiny here. On the basis of the very detailed review of revenue recycling in Speck (2006) it is possible to make the following observations:

- Sweden and Finland have mainly recycled revenue by lowering income taxes. For Sweden it has for many years been a tax policy aim to lower the pressure from income taxation on labour costs. The tax reforms in these two countries have aimed at a lowering of direct income taxes and the carbon-energy taxes have contributed to securing alternative revenues for some, but not all, of the income tax reductions. This observation applies for Sweden's early environmental tax reform (1989) as well as the most recent phase (after 2001). It also applies to Finland for the more comprehensive tax shifts introduced since 1996, whereas in the first phase revenues were small and the recycling not very transparent.

- Denmark and the UK, on the other hand, have followed the recommendations from the fiscal conventionalists more closely, e.g. revenues have been aimed predominantly at a lowering of employers' social security contributions, so as to avoid inflationary effects. However, because of the imbalance between energy consumption on the one hand and numbers of employees on the other, the lowering of social security contributions does not necessarily, at the company level, lead to full compensation of the individual company. The imbalance has then, in Denmark as well as in the UK, been mitigated via the various mechanisms for energy-intensive industries, such as agreements and reduced rates for heavy industries. The real purpose of the exemptions seems to have been to avoid the tax interaction effects. Finally, both countries have earmarked some revenues (5-20%) for direct energy efficiency subsidies, e.g. via the Carbon Trust in the UK, perhaps out of concerns that incentives would otherwise be too weak.

- Netherlands and Germany have followed 'mixed' approaches. The Dutch reduced income taxation in the initial phase; and a particular trait was the social concerns that led to the increase in the basic tax-free allowance for income as well as to complicated formulae for exempting basic consumption of electricity and gas (Vermeend and van der Vaart, 1998:11). In the second phase, the Dutch adhered more to the fiscal conventionalists and reduced the employers' social security contribution wage component, but they also reduced corporate taxes. In Germany, the ecological tax reform split the revenue recycling equally between reduction of employers' and employees' social security contributions; hence establishing a programme of revenue recycling less concerned with fiscal orthodoxy and more with political appeal, taking into account that the eco-tax reform aimed equally at gasoline prices and fuels as such.

- Slovenia, according to its official report to the UNFCC in 2002, does regard its package of increased carbon-energy taxes as an Environmental Tax Reform, but the authors of this paper have not been able to trace the specific revenue recycling approach.

Hence we can summarise the observations on the revenue recycling approaches by dividing the member states in question into three different groups; the fiscal conventionalists (UK and Denmark), the fiscal pragmatists (Sweden and Finland) and finally the political pragmatists (Netherlands and Germany). The pragmatists are so labelled, because reforms were designed so as to accommodate the prevalent pressing concerns with the tax systems and the electorate, rather than with fiscal theory.

2.3 Assessment of member state approaches

The initially diverse mitigation and compensation efforts have been brought more into line especially due to two pieces of European regulation; the Energy Taxation Directive from 2003 and the Community Guidelines on State aid for Environmental Protection from 2001 (the so-called Environmental Guidelines, cf. EC, 2001). Whereas the Energy Taxation Directive provides for minimum tax rates for a range of energy products, the Environmental Guidelines are significant in establishing the requirements for approval of derogations or exemptions from these as well as from unilaterally imposed taxes.

The Environmental Guidelines take a functional view on state aid, so that when there are selective exemptions from domestic carbon-energy taxes there is a requirement for approval from the European Commission. Initial doubts about this requirement among some member states withered away after the Adria-Vienna pipeline case ruling from the European Court of Justice in 2001 (Sutter, 2001). The new member states, Finland, Sweden and Slovenia, as well as the older member states, Denmark, Netherlands, Germany and UK, have had to adapt their mitigation efforts to the European legal framework.

The state aid guidelines offer certain opportunities for reducing the tax rates of energy-intensive industries, especially if these are higher than the EU's minimum tax rates. These opportunities are to some extent modelled on the basis of the 1995 decision regarding the CO_2 taxation scheme in Denmark, the first member state to obtain explicit Commission approval of its carbon-energy taxation system. As agreements between energy-intensive industries and the relevant authorities played a certain role in obtaining tax rate reductions in the Danish scheme, it was natural that the Commission's state aid guidelines reflected the role of agreements *vis-à-vis* selective tax reductions as accepted in the Danish case.

Hence the Danish scheme, and the subsequent state aid guidelines, provided a menu of acceptable solutions in relation to mitigation efforts that surfaced in the decisions in the German and UK schemes. It is therefore not surprising that agreements as an instrument play a key role in both the German and British cases. Conversely, agreements as a policy instrument are absent in the Swedish, Finnish and Slovenian schemes which were devised prior to the EU membership of these countries. And although the Dutch have a notorious practice of long-term agreements for energy efficiency, these agreements are not directly linked with the derogations from energy taxes, as the Dutch established their tax system as a response to the relative failure of the agreements to deliver on the desired CO_2 reductions.

The Swedish and Finnish systems share with the German and Dutch schemes the use of a 'threshold' above which one or more reduced tax rates apply for a range of fuels. The thresholds themselves vary significantly however; in the Finnish case only about 12 companies find themselves above the threshold, whereas in the German case about 1,600 companies rely on the 'spitzen-ausgleich' (Bach, 2005:17). The state aid guidelines are relatively taciturn on the use of thresholds, as well as on the principles of establishing these. While it would appear that a threshold is not discriminatory because all firms with energy consumption above the threshold are able to benefit from the reduced rates, some doubts must be expressed when the threshold is selective, for instance when applying only to some energy carriers and not to others, or in other ways applied in a narrow fashion that favours particular sectors or companies. It appears that these four member states have designed the thresholds to accommodate to some extent the specific competitiveness concerns relating to *their* domestic industries and the conventional fuel choices; while Finland appears to display concern mainly for its pulp and paper industry, the Dutch scheme appears to be designed especially to mitigate competitiveness concerns for its very energy-intensive chemical industry. As for Sweden and especially Germany a broader range of energy-intensive industries are of concern.

In contrast to the four above-mentioned member states, the UK and Denmark provide relief to a range of sectors and industrial processes in terms of reduced tax rates. These reductions are to some extent contingent upon agreements and binding targets for energy efficiency. While the UK provides reduced rates for coal, gas and electricity, Denmark allows for reductions for all fuels but not for electricity. Germany also offers reduced tax rates for industry, but in the German case there are no requirements for agreements. The reason is that the German reductions are available for all sectors, contrary to the case in Denmark and the UK where they are only available for certain processes or sectors. The non-discriminatory reductions in the German system imply that no state aid issues apparently have arisen with these; although the use of the EU minimum tax rate for coal but not for other fuels seems to convey a specific advantage to the iron and steel industry.

3 The framework for mitigation: state aid issues and the Energy Taxation Directive

The legal framework for granting special tax provisions that functionally are regarded as a form of state aid is the Community Guidelines on State aid for Environmental Protection (the so-called Environmental Guidelines, EC, 2001)[3] and the 2003 EC 'Taxation of Energy Products Directive' (Directive 2003/96/EC, EC 2003). The 2001 Environmental Guidelines replaced the 1994 Environmental Guidelines and tightened the conditions under which special tax provisions can be granted. In addition, the 2003 'Taxation of Energy Products Directive' is important as it widens the scope of the energy taxation framework from mineral oil fuels to a broader range of energy products, including electricity, natural gas and coal. The main relevance of this new directive is the fact that minimum excise tax rates have been set, which has had a clear effect on the granting of special tax provisions.

The Environmental Guidelines in combination with the Energy Taxation Directive set the rules under which special tax provisions may be granted. For example, when an ETR is introduced in one of the EU Member States reduced energy tax rates can be granted to energy-intensive industries – as opposed to other industrial sectors and households – if the reduced energy tax rates are still above the minimum excise tax rates established under the Energy Taxation Directive. Further reductions are possible if special rules are being considered which include agreements on introduction of energy saving measures.

Although the recycling of revenues generated by energy taxes is a fundamental part of any ETR, special recycling mechanisms can be applied to offset the potentially negative effects of the competitive situation on industrial sectors. One of the possibilities is to allocate parts of the revenue for the granting of subsidies for energy efficiency investments.

3.1 The requirements for reduced tax rates for energy-intensive industries

National governments have the duty to notify the European Commission in advance of any plan to grant state aid (the so-called '*notification requirement*') as the Commission is tasked with control of state aid. The legal framework for state aid is laid down in Article 87 and 88 of the EC Treaty and the substantial requirement of the incompatibility of state aid is established in Article 87(1). However, an absolute ban on state aid has never been envisaged, in particular for aid schemes which may have a beneficial impact in overall EU terms. A number of exceptions are therefore provided in Article 87(2) and (3) which are deemed to be compatible with the common market. In this context the Community Guidelines on State aid for Environmental Protection (the so-called 'Environmental Guidelines', EC, 2001) set out the conditions under which aid – also in form of special tax provisions - can be granted to firms for environmental protection in all sectors excluding agriculture.

The Environmental Guidelines distinguish between two different kinds of aid granted concerning taxes: 1) a tax levied as a result of a Community directive and 2) a new tax introduced by a member state unilaterally. In the former case there are two options: the first situation occurs when

[3] [3] The 2001 guidelines are applicable only until the end of 2007 and, currently, new guidelines are being drafted by the relevant institutions at the European Commission. A first version was sent out for consultation in May 2007. See the draft version of the revised guidelines: http://ec.europa.eu/comm/competition/state_aid/reform/guidelines_environment_en.pdf

a member state applies a tax higher than the EU minimum rate, but offers certain enterprises special tax provisions, i.e. a lower tax rate, but nevertheless one that is at least equal to the EU minimum. This type of aid might be justified in the Commission opinion. The second situation is when the member state applies the minimum tax rate as set in the directive, but then grants an exemption to certain companies. In that case, these enterprises do not even pay the minimum rate required by the Community. If this kind of exemption is not authorised according to the directive in question, it is incompatible with Article 87(1) of the EC Treaty. However, such a tax exemption can be in line with Article 87(1) under some specific regulations as listed in Paragraph 51 of the Environmental Guidelines.

If a member state introduces a tax as the result of an autonomous decision (i.e. absence of any form of tax harmonisation at the European level), a temporary tax exemption enabling certain firms to adapt to the new situation may be justified. However, this option is now obsolete as the 2003 Energy Products Taxation Directive established minimum tax rates for all energy products and partly differentiated between uses and users (household and business sector).

When special tax provisions are authorised by the Commission, then the duration of the aid measure is subject to a limited duration of five years where the aid is either 'degressive' (point 45 of Environmental Guidelines, EC, 2001) or when the aid intensity, i.e. the tax reduction, does not exceed 50 per cent (point 46 of Environmental Guidelines, EC, 2001). A derogation of ten years may also be granted but only when specific conditions are met (cf. point 51 of Environmental Guidelines, EC, 2001).

Apart from the Environmental Guidelines, the regulations and conditions laid down in the Energy Taxation Directive (EC, 2003) are also of relevance when assessing the possibility of energy tax reductions and exemptions. Article 17 of the directive states that tax reductions on the consumption of energy may be applied provided that the 'minimum levels of taxation prescribed in this Directive are respected on average for each business' (Article 17.1, EC, 2003).

However, the article states that certain conditions have to be fulfilled for energy tax reductions to be applied. Businesses either must fulfil the qualifying criteria of being 'energy-intensive' ('... the purchases of energy products and electricity amount to at least 3.,0 % of the production value or the national energy tax payable amounts to at least 0,5 % of the added value (Article 17.1(a))') or 'where agreements are concluded with undertakings or associations of undertakings, or where tradable permit schemes or equivalent arrangements are implemented, as far as they lead to the achievement of environmental protection objectives or to improvements in energy efficiency' (Article 17.1(b)).

Article 17.2 of the Energy Products Taxation Directive specifies that a level of taxation down to zero may be applied to energy products and electricity used by energy-intensive businesses. Furthermore, the directive permits that 'Member States may apply a level of taxation down to 50 % of the minimum levels in this Directive to energy products and electricity as defined in Article 2, when used by business entities as defined in Article 11, which are not energy-intensive as defined in paragraph 1 of this Article (Article 17.3)'. However, businesses benefiting from these special tax provisions have to enter into some form of voluntary agreements, tradable permit schemes or equivalent arrangements which '…must lead to the achievement of environmental objectives or increased energy efficiency, broadly equivalent to what would have been achieved if the standard Community minimum rates had been observed (Article 17.4)'.

The legislative framework undoubtedly permits special tax provisions to be granted to industries, as reflected in current practice. Interesting to note is the fact that the complete tax exemption of energy products still exists, but that EU member states are required to introduce energy taxes levied on all energy products during the coming years.

3.2 The role of agreements in energy savings

The analysis so far shows that reduction in energy tax rates sometimes needs to be combined with agreements aiming to improve energy efficiency. As discussed above, such agreements are one of the possible conditions to be met for reduction in energy tax rates to be authorised by the European Commission. Therefore it is of no surprise that such agreements are widespread in the ETR countries.

Voluntary agreements are a rather common policy instrument and an integral part of Dutch environmental management policies. Already in the 1980s long-term agreements between the Ministry of Economic Affairs and representatives of different economic sectors have been concluded. The environmental agreements (so called 'covenants') have in common that a target of increased energy efficiency is combined with legally binding CO_2 reduction targets. Additional support is provided to the companies in form of some level of tax reduction for investment in clean technologies, financial assistance to the companies entering into such voluntary agreement and for detailed audits of the industries' facilities.

The Danish energy taxation scheme is also closely bound with energy savings agreements as businesses are entitled to lower energy tax rates if they sign such an agreement with the Danish Energy Agency. Businesses entering such voluntary energy savings agreements have to set up an energy management system including an energy audit, staff training, procurement policies favouring energy efficiency and annual progress reports. In addition, the enterprise must commit to an energy saving target and has to enter into an agreement with the government to be eligible for a partial reimbursement of the energy tax. However, the partial reduction can be revoked if the obligations are not being fulfilled, i.e. in case of non-compliance.

The self-commitment of the German industry must be considered in the context of the energy tax rate reduction. This commitment entered into force four years before the ecological tax reform started in 1999, i.e. in 1995. Crucial points of the ETR were the increase in energy tax rates, the introduction of an electricity tax and a scheme of exemptions for industry. One of the reasons of the special tax provision was the voluntary agreement which foresaw that German industry would reduce CO_2 emissions by up to 20 percent until 2005. It should also be mentioned that one of the motives of the German industry for entering into the voluntary agreement was the promise of the German government to abstain from any additional policy measures aiming to reduce CO_2 emissions.

The UK also makes use of agreements as part of its climate change policy, in particular when the climate change levy (CCL) was announced in 1999. The basic principle of the climate change agreements (CCA) has features in common with the other schemes implemented in EU Member States as 'it was made clear that energy-intensive sectors would have the chance to negotiate a reduced rate of tax in return for targets of reduced energy use (Ekins and Etheridge, 2006, p.2072)'. The actual scheme is of the following design:

> '44 agreements (CCAs) were concluded with different sectors, with different sites (target units, or TUs) individually signed up within the sectors. The agreements set out targets related to energy use or carbon emissions over this decade, comprising a final target in 2010 and 'milestone' interim targets for 2002, 2004, 2006 and 2008. The CCL on the TUs in all the sectors with CCAs was set for the first target period (to April 2003) at 20% of the rate charged on other industrial and commercial energy use. If a sector, or the

individual TUs within it, met their 'milestone' targets, the sector (or the complying TUs) would be 're-certified' (i.e. entitled to the reduced CCL rate for the next target period, the following 2 years). If the target was not met, the non-complying TUs would have to pay the full rate of the CCL on their energy use in the next target period. This provided a powerful incentive for the sectors and TUs to meet their targets' (Ekins and Etheridge, 2006, p.2072).

The reduction targets were negotiated between each individual industry sector and the government (Department for the Environment, Food and Rural Affairs) and, by and large, were achieved by the sectors. In fact, the results of the first target period showed a very considerable over-achievement by most sectors compared with their 2002 milestone targets. In aggregate, the results showed that overall 221 PJ less energy had been consumed in the CCA sectors compared to the Base Years, which amounts to an absolute saving of 4.3 mtC (in the UK Climate Change Programme, it was envisaged that the CCAs would only save 2.5 mtC by 2010) (Ekins and Etheridge, 2006, p.2072)'.

An interpretation of this result is that agreements on energy savings may be effective, but it can further be assumed that one of the reasons for the effectiveness in reducing CO_2 emissions relates to the penalty payment for non-compliance in the form of withdrawal of the special tax provision. It is lack of full compliance with the voluntary targets and the absence of clear rules for penalties that has caused difficulties with the extension of the German scheme for 'spitzen-ausgleich'.

4 Winners and losers in ETR

Concerns about the impacts of ETR on competitiveness of particular sectors represent the underlying reason why member states seek to obtain exemptions and special arrangements in this area. While the Energy Taxation Directive stipulates that exemptions should be limited to 5 or a maximum of 10 years, it contains on the other hand basic exemptions for dual use of fuels, and for certain uses of electricity in metallurgical industries as well as for mineralogical industries in general. As revealed in this paper member states make different use of these exemption mechanisms.

From an environmental economic point of view it would be desirable to avoid the numerous exemptions and to tax carbon-energy at a uniform rate. With a uniform carbon-energy tax rate the signal would be clear to the market about what level of abatement costs it would be efficient to accept.

In the following we explore the premises of the exemptions by returning to the sectoral company perspective; what are the costs of ETR to industries and to which extent can these costs be compensated by revenue recycling through a lowering of the employers' social security contributions (SSC)? We take advantage of the COMETR database to explore the distributional implications of ETR for the various industry sectors.

From the company perspective the increased level of carbon-energy taxation is offset by two factors: 1) revenue recycling by reducing SSC, and 2) improved energy efficiency which leads to lower energy costs per unit of output (cf. elasticities derived in Enevoldsen et al., 2007).

A third factor is at play, the so-called Porter effect, i.e. the increase in output as a result of the pressure to innovate and become more competitive. While the existence of such an effect was suggested by the panel regression analysis of the COMETR project, we will for the sake of transparency leave it aside for the initial overview of the sectoral implications of ETR.

Table 1 provides an overview of the share of ETR net expenditures at the sectoral level as a share of the gross operating surplus[4] (GOS) for three countries for which the revenue recycling data could be disaggregated to the sectoral level. The revenue data obtained from national sources has been split into sectors according to Eurostat employment data.

It is evident that for most sectors ETR appears to be a cost, even when the accelerated energy efficiency improvements which can be related to the tax increases are taken into account. However, the energy productivity improvements which can be related to the tax increases are relatively minor compared with the gross energy productivity improvements that have taken place during the last decade, so that Table 1 provides a careful estimate of the net balance of ETR without taking into account the Porter effect as such. (The elasticities derived for energy savings in the Nordic sectors have also been applied to German sectors).

Table 1 The net costs of ETR in per cent of gross operating surplus, taking into account revenue recycling to employers only, as well as the share of improved energy efficiency related to the increase in carbon-energy taxes.

	Meat	Paper	Chem.	Pharm.	Glass	Cement	Ferrous	Non-ferrous
$DK_{96\text{-}02}$	-0.8		-0.1	-0.1	-0.3	1.4	-2.3	-0.9
$DE_{99\text{-}02}$		1.2		1.1	0.2	-0.4	-1.6	-2.1
$SE_{96\text{-}02}$	0.0	0.0	-0.5	0.0	-1.5	-3.7	-2.9	-0.3

When interpreting the results of Table 1 it needs to be borne in mind that Sweden did not recycle revenue via a lowering of SSC, but via lowering of income taxes. Nevertheless, the burden of ETR falls mainly on the most energy-intensive sectors, e.g. glass, cement and ferrous metals. Cement in particular has not had benefit from the same exemptions as elsewhere in EU. The impacts of revenue recycling via lowering of income taxes on salary levels cannot be accounted for here (readers interested in the broader macro-economic view are referred to the E3ME-results for Sweden).

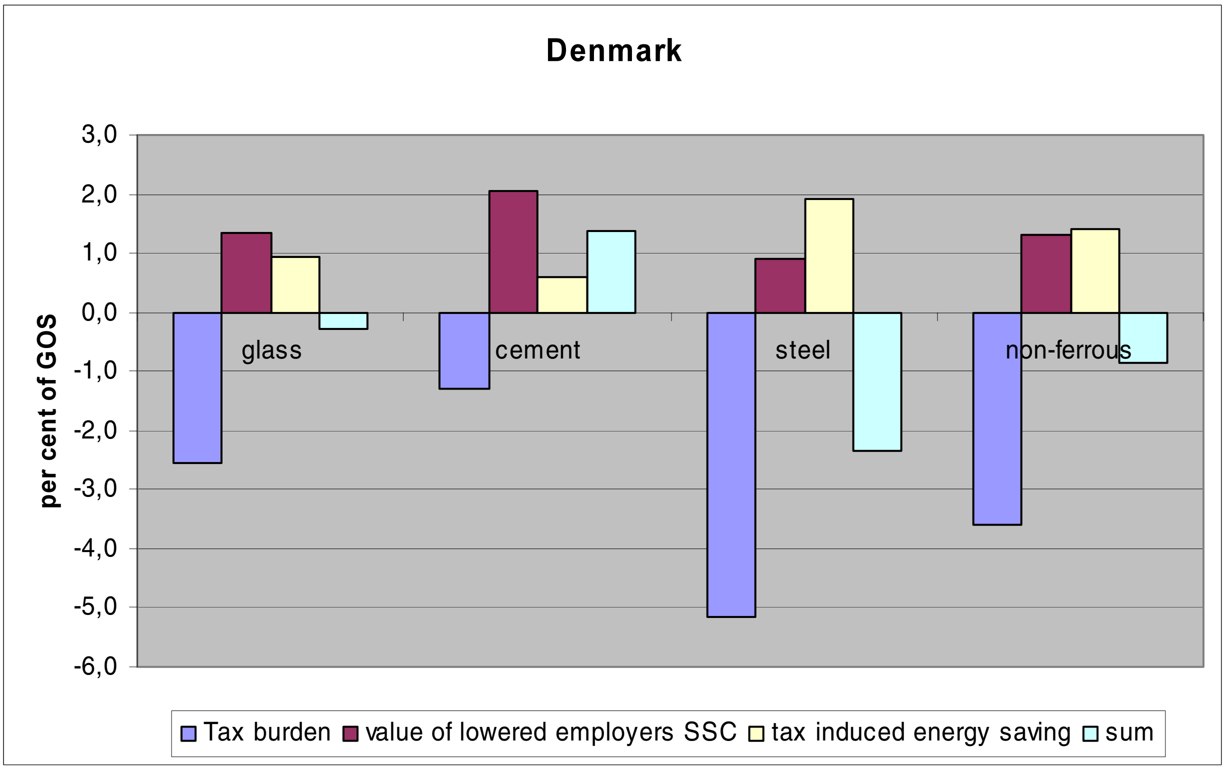
In the case of Germany about 50 per cent of the revenue was recycled via lowering of employers SSC and so the burden mainly accrues to the most energy-intensive industries, in particular ferrous and non-ferrous metals. However, the figures do not incorporate the 'spitzen-ausgleich' exemption mechanism, e.g. the thresholds for peak tax burdens, and so Table 1 actually overestimates the net costs of ETR for energy-intensive industries in Germany (the same caveat is valid for Figures 2 and 5). The German ex-post compensation scheme is rather complex, and more detailed national studies (Bach, 2005) have made attempts to account for the 'spitzen-ausgleich'.

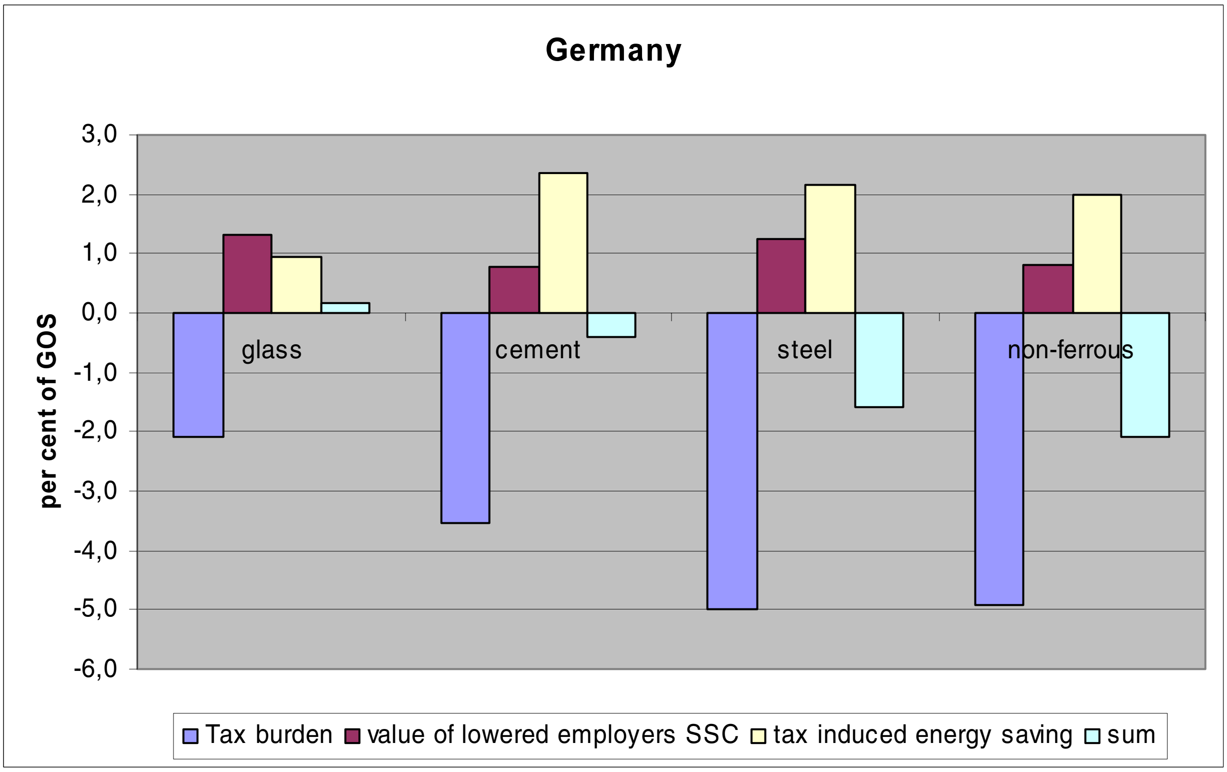
In the case of Denmark the complex tax exemption mechanisms, combined with the unusually high tax rate for heating, have evened out the tax burdens among sectors, but ferrous industries

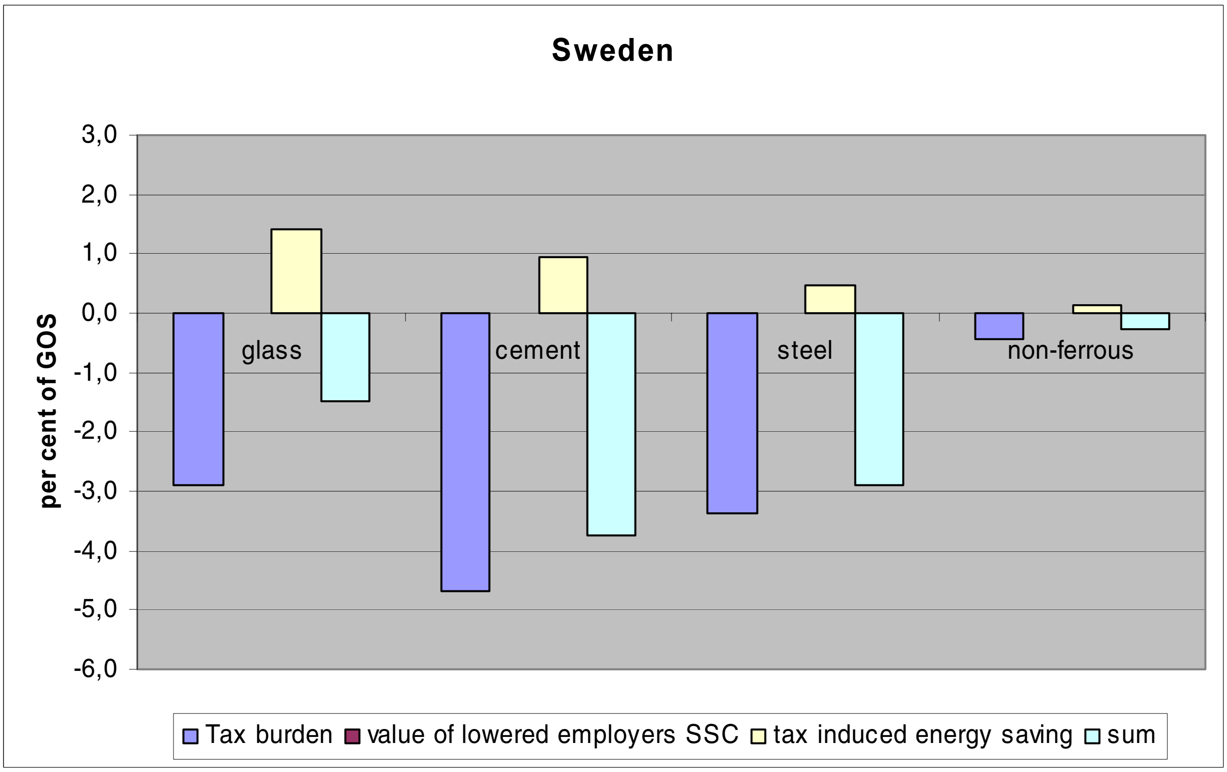
[4] Gross operating surplus denotes the surplus of activities before consumption of fixed capital.

appear to have experienced some inroads in their gross operating surplus. Cement, surprisingly, has accomplished a positive net benefit from ETR, this is due to the substantial fuel shifts carried out (in particular substitution to the use of waste as fuel) and the energy efficiency improvements attained.

Figures 1, 2 and 3 decompose the net effects of ETR for the three countries into the gross carbon-energy tax payments, the revenue recycling and the gains from improved energy efficiency respectively.







The decomposition of the ETR costs at the sectoral level shown in Figures 1, 2 and 3 for Denmark, Germany and Sweden show that ETR, even with the exemption mechanisms in place, only in exceptional cases induces a gain for energy-intensive industries. The general pattern is one of a burden for the most energy-intensive industries. Conversely, the less energy-intensive industries (meat, pharmaceuticals, paper products) have managed to offset the costs of ETR; substantial gains are however not apparent either.

Some degree of revenue recycling of employers' social security contributions (SSC) is an important measure to reduce the direct costs of ETR, as reflected in the lower net costs for Danish and German industries as compared to Swedish industries. Still, the importance of revenue recycling should not be overemphasized, as in six of the eight Danish and German sectors the savings via improved energy efficiency are more significant than the revenue recycling itself.

From the sectoral perspective the burden for energy-intensive industries is negative but modest. For cement and glass it is less than 1 per cent of the gross operating surplus when there is some revenue recycling of employers' SSC, while for ferrous and non-ferrous metals it appears to have reached in some cases 2 per cent of gross operating surplus. In the Swedish case, with no SSC-revenue recycling, the costs are estimated to be higher and up to 4 per cent of gross operating surplus for cement and steel. Company managers in energy-intensive industries may not have appreciated the tax-induced improvements in energy efficiency and may have focused more on the gross burden of ETR, which, unadjusted for the gains, has reached up to 5 per cent of the gross operating surplus for some energy-intensive industries in all three countries.

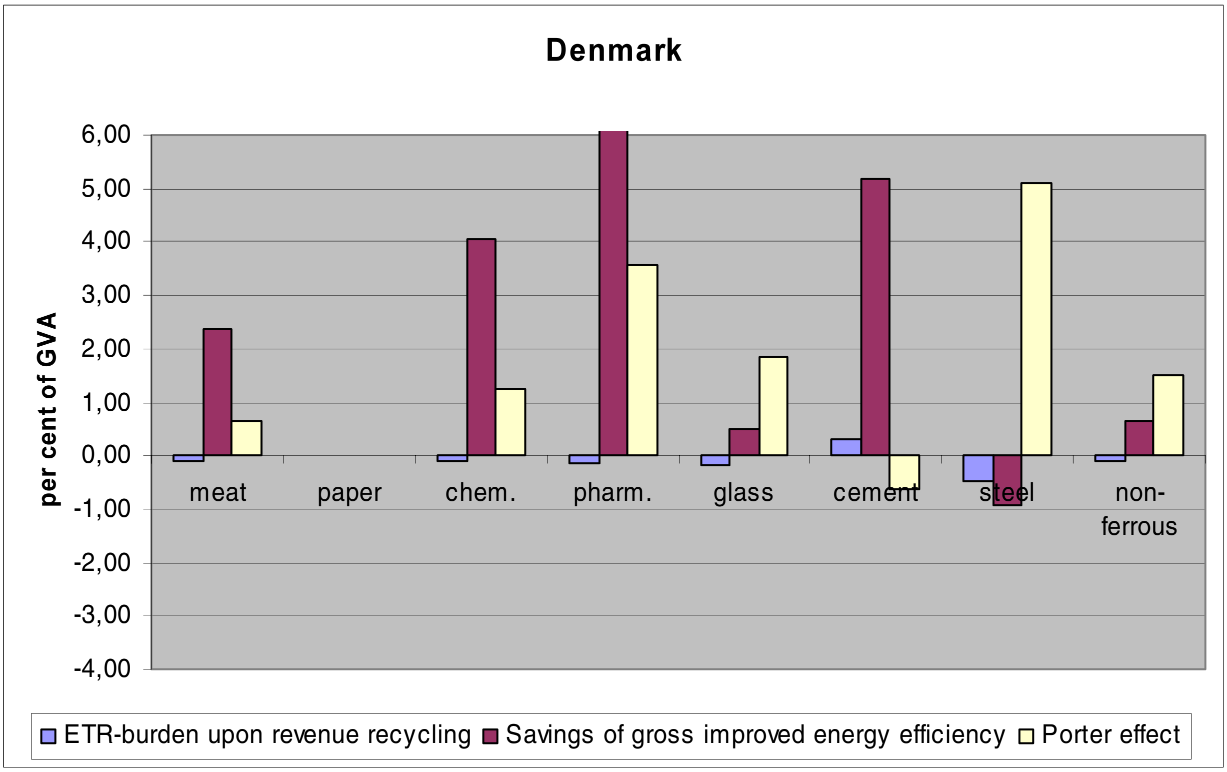
The claim of the Porter hypothesis is actually not that energy taxation will induce sufficient energy savings to even out the increased tax burden. Porter's hypothesis is rather that increased carbon-energy taxation will in the longer term pressure industries to innovate both their processes and products so as to become more competitive and win market shares.

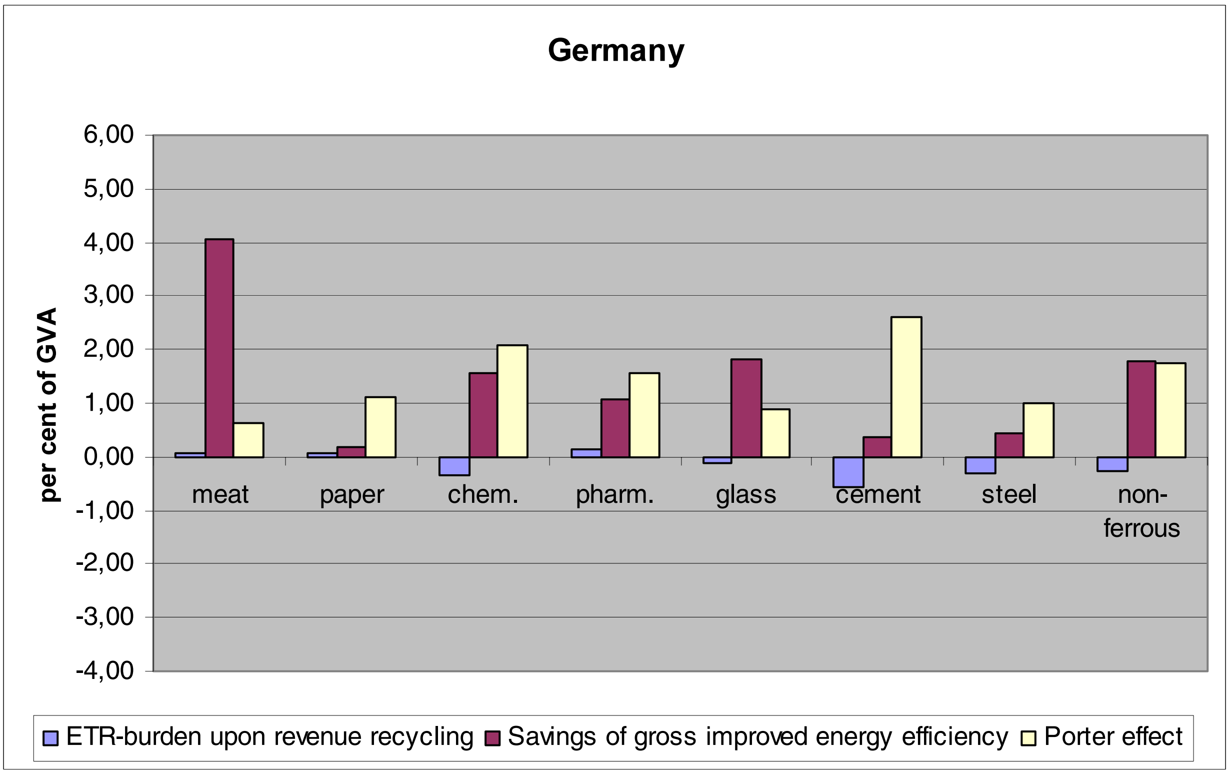
In the COMETR project both the E3ME modelling of the macro-economic impacts and the panel regression analysis of the impact of energy taxes in 56 industrial sectors pointed to the existence of such 'hidden' Porter demand effects. In the following we put the sectoral costs of ETR, cf. above, in perspective in relation to these 'Porter' effects as well as the gross energy savings attained by industries in the wake of ETR.

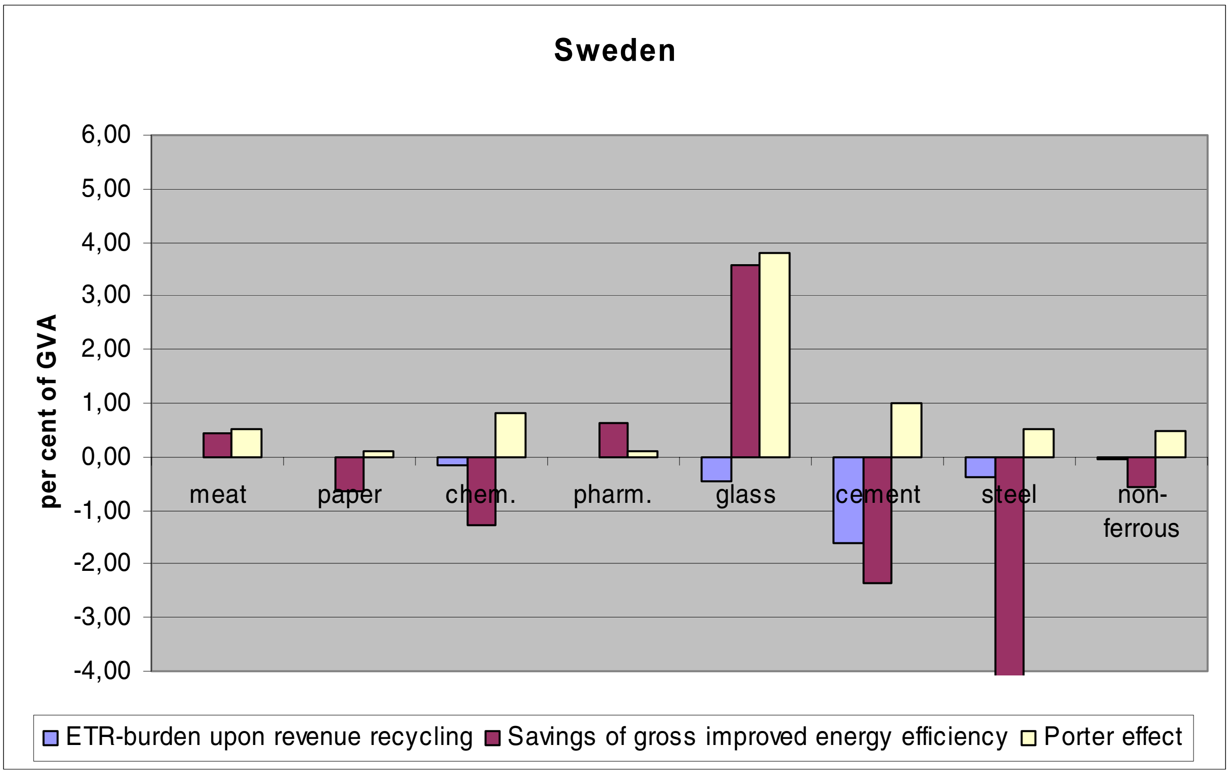
The gross energy savings are the costs foregone per GJ of output at the current energy prices. Bearing in mind that above only the *accelerated* energy savings that could be attributed directly to the annual tax rate increases were included, we show here the value of gross energy savings accomplished by the various sectors. The additional energy efficiency savings attained in most sectors are far higher than can be attributed statistically to the tax rate increases. As energy prices were relatively stable over the period analysed here, changes in underlying fuel prices can not explain the savings.

In most cases where ETR caused increased costs these are more than offset by the gross energy savings. To some extent the gross energy savings reflect 'business-as-usual' and only those energy savings attributed to the tax rate increases should be included when accounting for the impacts of ETR, as approached above. Nevertheless, the gross energy savings accomplished do put the ETR costs in an illuminating perspective.

Figures 4, 5 and 6 provide an overview of the costs of the ETR burden relative to the gross energy efficiency savings. In addition the three figures provide an estimate for the Porter demand effect on the basis of the relationships derived in the panel regression analysis, which identified a statistically very significant relationship. However, as a minor degree of multi-collinearity in that analysis could not be ruled out, the Porter demand effects must remain a best guess and their quantification would require further efforts with improved econometric techniques.







First of all, the costs of ETR – now as a share of gross value added (GVA) – are in practically all sectors an order of magnitude lower than the gross energy efficiency savings attained, as well as the estimated Porter effects. Important exceptions to this general trend can be noticed for cement and steel industries. Here the gross energy savings are not impressive in relation to the ETR burden, apart from in the case of Danish cement.

As noted above the ETR costs for Germany are overestimated, as the value of the *Spitzen-ausgleich* has not been included. As the ETR costs as a share of GVA are nevertheless very modest this observation is without implications for the following inspection of the differences between Denmark, Germany and Sweden, which to some extent are striking and deserve attention.

For chemicals, pharmaceuticals and cement the gross energy savings are far more significant in Denmark than in either of the other two countries. Conversely Germany has the lead for ferrous and non-ferrous metals and meat. Sweden excels in its glass industry only, while several other sectors saw their energy efficiency deteriorate.

Swedish steel is an interesting case as energy consumption has increased, particularly with the use of coal and coke, while economic output has been stagnant. It seems that fuel switches introduced during the initial 'ideal' carbon-energy tax scheme in 1992-93 were reversed in the latter half of the 1990s, which may help explain the deterioration in performance of this and other Swedish sectors (as well as the exemption mechanism for coal and coke in ferrous and non-ferrous metals).

For Germany, ETR was initiated as late as 1999 and has been under implementation for a shorter period of time than ETR in Denmark and Sweden, which we analyse here for the period from 1996 (and for all three countries up to 2002). Previous research has shown that the time span required for adaptation to increased energy taxation is about 4 years, so the time span should be sufficient to capture the full effects in Germany. In Germany, 50% of the revenue has been recycled to lower employers' social security contributions, and this helps to create a positive balance for ETR for three sectors, even without considering improved energy efficiency savings and Porter effects.

To sum up, while for most energy-intensive sectors the tax-induced energy savings were not sufficient to offset the ETR burden, this burden remains for most sectors an order of magnitude lower than the overall energy savings accomplished during the years of ETR.

Cement and steel issues

The main problem appears to be with the cement and steel sectors, which seem to have had some difficulties absorbing the ETR burden; although Danish cement stands out as a notable exception to this pattern with its considerable energy efficiency savings. These savings were achieved by lowering energy intensity from approx. 67 GJ/1000 euro output to a level of 50 GJ/1000 euro output in just seven years, e.g. by 25 per cent. Still, Sweden's energy intensity for cement is at about the same level as Denmark's and Germany's is even lower (40 GJ/1000 euro output), so the pattern for Danish cement may reflect that a backlog of improvements was drawn upon.

In Sweden and Germany, cement has been subject to higher tax burdens than Danish cement (0.35 euro/GJ and 0.21 euro/GJ, respectively, versus 0.05 euro/GJ in Denmark (Ryelund, 2007)); nevertheless, cement's energy efficiency has not improved markedly in the two former countries either. It seems that Swedish cement was able to absorb the tax through a lowering of its energy costs by switching fuels, hence keeping overall energy costs roughly constant. In Denmark both fuel switching and energy savings were involved. The findings lead to the suggestion that more substantial tax rates would be required to induce further energy savings, and that the industry might be facing a technology threshold that would require additional effort to transcend. A recent IEA report (2007) states that by switching to dry process rotary kilns the energy efficiency of cement industries could be improved by up to 50 per cent compared with traditional wet process technologies. Investments required for cement plants are significant and amount to approximately three years of turnover (Jilkova, Pisa and Christie, 2006). As cement accounts for about 10 per cent of total final industrial energy use, the potential contribution to energy savings from the use of best available technology is by no means trivial. Cement is not unequivocally a price-taker; the value-to-weight ratio of cement does not allow for long-distance land transport. Direct access to port facilities can extend the range of trade activities, however. After the food processing sector, the non-metallic minerals products sector, the parent sector of cement, is the least trade intensive, cf. COMETR's market structure analysis (Scott, Keeney and 2006). It is also ranked as the least sensitive in terms of price-setting power.

With respect to steel it is second to cement in energy intensity, with levels varying from 19 GJ/1000 euro output in Germany over 13 GJ/1000 euro output in Sweden and only 5 GJ/1000 euro output in Denmark, where plants rely mainly on the technology of electric arc furnaces. The differences are believed also to reflect differences in average plant size and product characteristics as well (including wider use of scrap steel in Denmark). In terms of economic output the sectors are not declining and they are not 'sunset' industries as such. For steel we identify the highest effective tax burden in Denmark (0.77 euro/GJ), as opposed to approx. 0.27 euro/GJ in Sweden and Germany. As mentioned above, energy efficiency deteriorated in Sweden's steel industry; and the same trend, although less pronounced, has been identified for Denmark, whereas for Germany a very modest increase can be identified for the steel sector. The effective tax burden per GJ for the steel sector is at the same level as tax burdens in other sectors, including the energy-intensive chemicals sector. A closer inspection of the energy costs suggests that the modest tax burdens have been absorbed by fuel shifts that entailed a lowering of energy expenses. As the lowering just about offsets the increased tax burden no net improvement in energy efficiency and productivity is evident.

A recent IEA report which reviews technology options in the steel industry shows that a broad menu of technological processes are employed in the sector (IEA, 2007:108). The traditional basic oxygen furnace (BOF) method is one of the most energy- and carbon-intensive, and the options for improvement in energy efficiency are relatively limited. A switch to use of electric arc furnaces based on gas would entail more significant savings in relation to carbon emissions. Furthermore, by switching from pig iron to use of scrap iron in traditional electric arc furnaces, CO_2 emissions per tonne of steel can be reduced to 20 per cent of the level with the traditional BOF method. The main issue here is that the method is subject to the constraint of the limited availability of scrap iron of suitable quality. Conventional BOF methods continue to account for 2/3 of production capacity in Europe, while, for example, electric arc furnaces account for only about 30 per cent of steel production in Germany and 20 per cent in the UK. As electric arc furnaces rely on electricity rather than coal, the production method can be based on hydropower or gas, as is the case in Slovenia and Denmark, rather than coal, as predominantly used in the sector in Germany and Sweden (Christie, Hanzl and Scott, 2006: 31). As the iron and steel industry is clearly a price-taker, limited opportunities exist for passing on the costs of carbon, if factored into the cost structure via ETR. However, a more phased introduction of ETR, with some revenue recycling for an investment programme to renew production technologies, would allow for an implicit fuel shift in favour of electric arc furnaces. Improved levels of steel recycling would furthermore increase the capacity of scrap-based steel processing and, as the sector's location decisions are tied more with availability of iron than with energy requirements, this might support the sector in continuing its production activities within the EU.

5 Mitigation in a regulatory environment with interaction effects between emissions trading and carbon-energy taxes

Establishment of a CO_2 emissions trading system in the European Union has created a more complicated regulatory environment, in which carbon-energy taxation now coexists with trading of emission certificates.

The emissions trading system covers large installations, i.e. power plants larger than 20MW, as well as refineries and certain energy-intensive industries, notably ferrous metals, cement, glass, ceramic products as well as pulp and paper. Member states can further extend the trading system to other energy-intensive industries.

As emission certificates are grandfathered to industries, the costs of the scheme arise via two routes. Direct costs may arise as industries need to acquire certificates for additional production activities. Indirect costs arise as power plants factor the value of certificates into power prices. Due to the power producers' ability to pass on costs, the national allocation plans have in most cases provided certificates to industry matching historical emissions; whereas allocation to power plants, for several member states, has been restricted to levels lower than those of historical emissions. This implies that the main way according to which the ETS can impact the competitiveness of firms is via pass-through [via the passing on of costs] to power prices.

Numerous studies have investigated pass-through to power prices. The most pessimistic studies assume a 100 per cent pass-through rate; e.g. McKinsey comes to a figure of 10 €/MWh for a 20 euro allowance price. However, several studies show that the pass-through rate will only be 100 per cent during the time when power demand exceeds the base load, and where it is coal or lignite plants that set the marginal price (Sijm et al., 2006). In the seasons and periods where hydropower or nuclear power set the marginal price, it is not likely that power operators will be able to factor in the full value of the certificates. One study, for Germany and the Netherlands, comes to a pass-through rate of 40-60 per cent. The IEA furthermore points out that large parts of the European electricity market are not yet fully liberalised and that price regulations will restrict pass-through (Reinaud, 2007). Nevertheless, the IEA points to the Nordic electricity market (Nordpool) as one region where the electricity trade has been successfully liberalised and where pass-through of ETS costs should be expected. Due to the significance of hydro- and nuclear power, one Finnish study concludes that the average pass-through rate on the Nordpool exchange should be in the range of 40 per cent, e.g. 4 euro/MWh for a 20 euro allowance price. This would mean that the range indicated by the various studies and market analysts runs from 4-10 euro/MWh for the power sector with a 20 Euro allocation price. This pass-through cost can be compared with CO_2 tax rates on electricity in the range of 6-12 euro/MWh for smaller business users in the Netherlands, UK, Germany and Denmark, and 0.5 euro/MWh for large users (energy-intensive industries). In conclusion, the ETS system will from 2008 most likely effectively increase the CO_2 costs per kWh for the covered energy-intensive industries in EU-27 to a level comparable to the level of smaller business users in the ETR countries. Still, as fuel uses other than electricity are not affected by pass-through, the overall impact is less than that of carbon-energy taxes levied on all fuels.

A double-regulation concern was raised as the European Council passed the ETS Directive. The concern relates to the need for carbon-energy taxation as a regulatory instrument in view of the existence of the ETS system. The ETS system divides stationary emitters into two sectors; ETS and non-ETS. The argument in support of the double-regulation concern is that as emissions from the ETS sector are fully regulated from the trade with certificates there is no further need for a regulatory tax. The ETS sets a cap for emissions from the ETS sector; if emissions exceed this cap additional allowances must be acquired on the market, possibly with the use of other flexible instruments as well.

Slovenia, Denmark and Sweden have been considering removal of carbon-energy taxation for installations covered by the ETS, but European Commission approval is still pending. The concerns centre upon the state aid rules as well as potential violation of the Energy Taxation Directive, and no decision has yet been reached. On one hand the Energy Taxation Directive foresees that installations covered by tradable quotas may be fully exempted from the minimum tax rates. The issue remains, though, whether the grandfathered allowances qualify as a fully-fledged scheme of tradable quotas. On the other hand the Energy Taxation Directive has a broader scope than carbon taxation; it also concerns security of energy supply and harmonisation of tax rates. As the ETS system has created a market where prices have shown to be very volatile, and as pass-through rates are very dependent on regional specificities of the power markets, the ETS system will not be likely to create a level playing field, as was the intention of the minimum tax rates, and there are concerns about the implications for the polluter-pays principle.

From the perspective adopted in this paper, with focus on mitigation and competitiveness concerns in view of the need to increase carbon-energy costs to accomplish the stabilisation target, we note that the ETS scheme will, for electricity, effectively offset the fiscal exemptions obtained by energy-intensive industries under ETR. However, as there is no revenue available for recycling under the grandfathered ETS scheme, no simple way exists in which to compensate energy-intensive industries for the additional burden, e.g. by lowering employers' social security contributions. Hence we foresee more substantial inroads into energy-intensive industries' gross operating surplus from ETS than from the pre-existing carbon-energy taxes introduced under ETR.

6 Conclusions

The environmental economists who initially advocated the use of economic instruments for environmental regulation, including in the field of climate policy (e.g. Pearce, 1991), did not address in detail the issues of competitiveness and mitigation. The special arrangements that have developed within the unilaterally introduced ETRs have, unfortunately, replaced the transparency and calculation methods of economic incentives with that which materialises when the heat of vested interests meets with the mists of tax legislation – a rather thick fog of exemptions.

In view of the need to accomplish a stabilisation of atmospheric carbon concentrations at a level of 450-550 ppm we have, in this paper, investigated the exemption and mitigation approaches adopted in the seven ETR countries, as well as the actual tax burdens of energy-intensive industries. The purpose of this investigation was to obtain a clearer view of the actual burden of ETR on industry, as well as some indication of the scale of costs before and after mitigation.

In terms of ex-ante measures for mitigation, all countries have offered energy-intensive industries exemptions and reductions in relation to tax bases and tax rates; but, despite the requirements of the Energy Taxation Directive, the specific exemptions vary to some extent between member states. Sweden, Finland and the Netherlands have a threshold in their carbon-energy tax legislation above which the national addition to the EU minimum rates do not apply for large energy users. However, while in the Dutch case the threshold is generally in place for all large consumers of gas and electricity, in Finland and Sweden the minimum rates apply only for industries where the tax burden exceeds a predefined share of gross value added.

In Germany, UK and Denmark, industries with energy efficiency agreements can have their tax payments refunded. However, while in Germany the minimum rate remains at 60 per cent of the nominal rate, the payments in the UK are generally at 20 per cent, while in Denmark they can be as low as 3 per cent. Also, the exemptions for specific fuels differ considerably; while in Germany the use of coal remains tax exempt for households and certain industrial uses, this fuel is subject to taxation in most other countries – most of which grant benefits under the Energy Taxation Directive exemptions allowed for metallurgical industries or power plants. The combination of general and specific energy tax rules combines to produce a complex mosaic of exemptions, making it difficult to make generalisations about prevailing conditions – conditions which vary entirely according to sector, energy carrier and country.

As to the ex-post approaches for mitigation, the countries can be divided into three groups; the fiscal conventionalists (Denmark and UK), which have adhered to revenue-neutrality through a lowering of employers' social security contributions; the political pragmatists (Sweden and Finland), which have preferred to lower their effective rates of income taxes; and finally the fiscal pragmatists (Germany and the Netherlands), which have chosen to combine lowering social security contributions (both employers' and employees') with lowering income tax.

The European Union's Energy Taxation Directive as well as the Commission's Guidelines for State Aid have in recent years (since 2003) been helpful in narrowing the differences in ex-ante mitigation measures, but have had little harmonising impact on ex-post measures. In particular the decisions on how to recycle revenues are entirely within the discretion of member state competencies, despite the significance of these as a compensation instrument.

In this paper we have explored the effective sectoral burdens of ETR for energy-intensive industries with respect to three countries; Denmark, Germany and Sweden (one from each of the three above-mentioned categories of ETR). Without taking either revenue-recycling or energy efficiency into account, the burden of ETR for energy-intensive sectors, net of the value of exemptions and reductions, has not exceeded 5 per cent of gross operating surplus in any sector in these countries. For Denmark and Germany the net burden, taking into account the value of the revenue recycling of employers' social security contributions and the tax-induced energy efficiency measures, has not exceeded 2 per cent of gross operating surplus for the most negatively affected sectors, ferrous and non-ferrous metals. For other energy-intensive industries, glass and cement, the burden has been in the region of 1 per cent. These figures do not include the German peak-tax - adjustment and so represent a conservative estimate of the costs for Germany.

Overall, the net costs of ETR are, in most sectors, exceeded by the value of the gains in energy efficiency which have been obtained over the same period of time. The exceptions to this pattern are Danish steel, the German steel and cement sectors as well as several Swedish energy-intensive sectors, where energy efficiency improvements have not been sufficient to offset the burden imposed by ETR. The troubled history of ETR in Sweden is believed to have produced a backlash, as energy-intensive industries increased energy consumption in response to the marked reduction in CO_2 taxation in relation to the initial level in 1991-92. The Swedish steel sector, for instance, increased its energy consumption while economic output remained constant. In Denmark and Germany, on the other hand, the costs of ETR are offset by gains in energy efficiency, while the potential Porter effect (improved competitiveness) as detected in other work packages, would come on top of these gains.

As technologies are available which allow for significant reductions of fuel use and carbon emissions in the most energy-intensive sectors, cement and steel, a gradual and announced reduction of exemptions would not necessarily endanger the economic activities of these sectors. A revenue-neutral shift in taxation from labour to carbon-energy primarily benefits labour-intensive sectors, but where the transport sector is included in the tax shift, the additional revenue which accrues could allow for higher levels of compensation for energy-intensive industries.

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