CARBON DIOXIDE, ENERGY TAXATION AND INDUSTRY: AN INPUT-OUTPUT ANALYSIS

Cathal O'Donoghue

February 1997

Working Paper No. 82

Cathal O'Donoghue
Statistics Dept., London School of Economics &
Dept. of Applied Economics, University of Cambridge.

CARBON DIOXIDE, ENERGY TAXATION AND INDUSTRY: AN INPUT-OUTPUT ANALYSIS.

Cathal O'Donoghue

Microsimulation Unit
Department of Applied Economics
University of Cambridge
Sidgwick Avenue
Cambridge CB3 9DE
England

phone 44-1223-335267
fax 44-1223-335299
email: co206@econ.cam.ac.uk

This paper is a draft document and should not be quoted without the author's permission. I would like to thank the following for comments: Sue Scott, Mike Chadwick, John Lawlor, Grainne Collins, Colin Rowat, Eamon Henry and John FitzGerald and participants at a seminar at Cambridge University.

1. Introduction

The greenhouse effect, which is predicted by many scientists to lead to global warming, is potentially one of the worlds most pressing environmental and economic problems at the moment. Global warming could lead to the melting of the polar ice caps, which in turn would lead to a rise in sea levels and its associated problems. Changing climates can also have a major effect on farming, leading to desertification of many areas. Emissions of carbon dioxide into the atmosphere is one of the major contributors to the greenhouse effect. To combat this, the European Commission has proposed that a carbon/energy tax be levied in order to reduce the emissions of carbon dioxide and to reduce consumption of non-renewable fuel sources.

There have been two studies which investigated carbon dioxide production in Ireland and the impact of a carbon tax: Scott (1992) and Fitz Gerald and Mc Coy (1992). Scott looked at the direct fuel and energy expenditure by households and assessed the distributional effect of a carbon tax. Fitz Gerald and Mc Coy modelled the macro-economic impact of a carbon tax. This paper will concentrate on modelling the carbon dioxide emissions across economic sectors and examine the static impact of a carbon tax. Industries would face cost pressures both directly through increased fuel prices for their own production and indirectly through increases in the prices of other inputs resulting from the tax's impact on their fuel inputs. Therefore an input-output analysis is used to investigate these issues.

2. Global Warming

Over the last 20 years scientists have highlighted the possibility of a global temperature rise as a result of a build up in the atmosphere of *greenhouse gasses*, Methane (CH_4), carbon dioxide (CO_2), chlorofluorocarbons (CFC's) and Nitrous Oxide (N_2O). Rises in the concentration of any of these gasses increases the amount of heat absorbed in the lower atmosphere. Their presence in the atmosphere is essential as greenhouse gasses which occur naturally in the atmosphere allow the Earth's surface temperature to average 15^o C. Without these, the temperature of the Earth would be only -18^oC. However, industrialisation over the last two centuries has caused an increase in the concentration of greenhouse gasses (GHG). For example, from around 1750 to today, the concentration of CO_2 in the atmosphere has increased from 270 parts per million to 360 ppmv. This resulted initially from deforestation and in later times from the burning of fossil fuels. The Intergovernmental Panel on Climate Change (IPCC), sponsored by the UN in 1990, predicted that global temperature would rise by about 0.7^oC. per decade over the next century if no remedial action were taken due to the rapid growth in GHGs emissions. CO_2 is by far the largest contributor to the greenhouse effect, producing in 1985 almost two thirds by volume of man-made greenhouse gas emissions.[1] In the European Union, Ireland

[1]European Commission (1992)

comes second after the Netherlands as a source of greenhouse gasses per capita[2], due to its large reliance on peat (which has a higher carbon content than other fossil fuels), livestock (methane) and to its lack of hydro electric and nuclear power. The Toronto agreement of 1988 called on industrialised countries to reduce their CO_2 emissions by 20% of their 1988 levels by the year 2000. See Cline (1991) for further details.

3. The Economics of Cutting Carbon Dioxide

The rationale for the state to step in to control pollution arises from the existence of externalities, which are costs (or benefits) imposed by the polluter on others. For example, individuals who dump raw sewage in rivers may not experience any cost in doing this, but impose costs on society such as smells, higher purification cost for drinking water, killing of fish stocks and other public health issues etc. Polluters will act, in terms of their product mix, technological use and production process on the basis of their private costs and benefits and not on the costs faced by society. In order to reduce the external cost of pollution control will be necessary either through regulation or through some market mechanism such as taxation.

Figure 3.1 below outlines on the Y-axis, the marginal costs faced by society and the polluter at different levels of pollution. The X-axis on this graph refers to the amount of pollution as a percentage of the pollution level which would exist if there were not any restriction. The marginal abatement cost (MAC) faced by the polluter will generally rise, with reducing levels of pollution, because it is assumed that cheaper methods of pollution abatement will be tried first. The marginal damage cost (MDC) of pollution faced by society will tend to rise with increasing pollution due to the fact that higher pollution levels cause proportionately more damage.

It is important to balance the cost of pollution control with the cost of pollution. Accordingly for theoretical reasons society's optimal position will be the quantity of pollution where the marginal cost to the polluter of abatement is equal to the marginal cost to society of damage. In that they both require monitoring systems and administrative systems to be effective, regulations and market mechanisms are similar. Regulations can be designed to achieve the same level of pollution reduction as market measures.

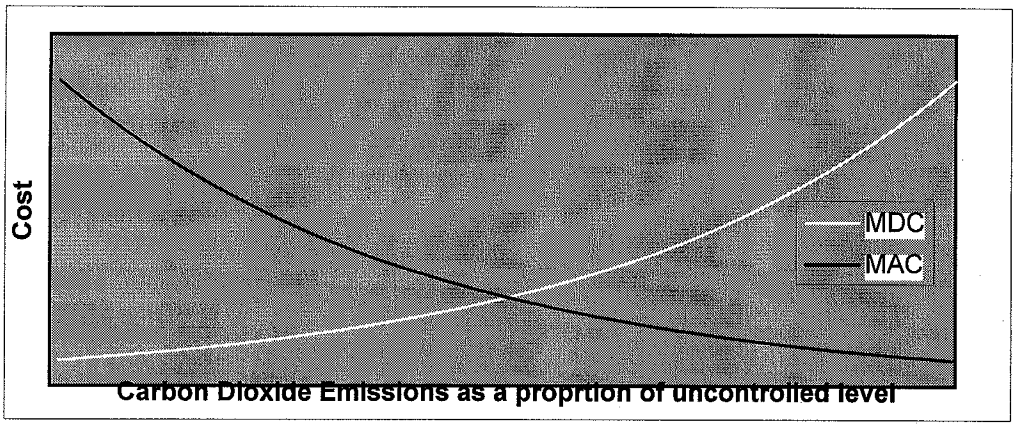
Traditionally, regulations have been the major instrument of environmental policy and have the advantage that if they are adhered to, environmental standards are actually achieved. However they are not dynamically efficient in the sense that once these standards are achieved, there is no further incentive to improve on them. In addition regulations are statically inefficient as they make no allowance for the fact that the cost of compliance can vary across sectors of the economy, which means that the total cost to the economy would be higher if regulations were used.

Market based instruments such as taxation can, by exploiting these cost differentials, lead to lower total compliance costs. They can also lead to continuous behavioural

[2]Convery (1994)

changes. An optimal tax would be set so as to reduce pollution to the point where the marginal social cost of pollution (MDC) and the marginal abatement cost (MAC) are equal. However it is difficult to determine the value of the external costs or the cost to society of pollution not taken into account by the polluter. Incentive taxes are therefore used to achieve a certain target. In some studies it has been found that a carbon tax has what is known as a double dividend: it can reduce CO_2 emissions as well as financing the reduction of distortionary taxes such as income tax. To give an example of this, Fitzgerald and McCoy (1992), using the ESRI Medium Term Model found that if revenues from a unilaterally imposed carbon tax in Ireland were used to reduce social insurance contributions, then GDP would rise as a result of the increased competitiveness of the Economy.

Figure 3.1 Efficient pollution abatement for a single polluting firm



However there are a number of disadvantages in using taxation to regulate the environment (Symons et al. 1994, Pearce 1991, Smith 1995). Short run energy elasticities are often lower than long run elasticities due to the time taken to switch to new technologies, which may slow down the achievement of targets. Simple environmental taxes may also not be appropriate where pollution is concentrated over time or in a certain location. More complicated measures or regulation would be more effective here. However neither of these are major issue in terms of global reductions of carbon dioxide emissions. Global warming is a problem that spans national boundaries and therefore is not limited to geographical areas, which highlights the necessity for international co-operation. As recent debates[3] have highlighted no progress can be made without this. This point has been incorporated into the model, as it has been assumed that carbon taxes will be levied on fuel inputs of imports as well. This an addition to the usual input-output model of Carbon Dioxide emissions which have disregarded the indirect production of Carbon dioxide due to the imports. The build up of greenhouse gasses in the atmosphere is a slow process, but also too is the reduction in GHG's, so that the long term strategy and the long term response to this strategy are what is important. Of more significance, energy elasticities are not known with reasonable certainty, which makes it difficult to assess the impact of a tax. An environmental tax too high may reduce pollution to below the socially optimal level, causing reductions in economic growth. Likewise, a tax too low will not achieve the desired targets.

[3] For example at the 1996 Meeting of the Intergovernmental Panel on Climate Change.

Only efficiency issues have been examined so far; another issue of importance is the distributional impact of environmental taxation. Taxes placed on essential goods such as domestic fuels will hit those at the bottom of the income distribution most[4], however fiscal measures such as increased transfer payments can be introduced to reduce the distributional impact[5].

Another problem with charging polluters is measuring how much they pollute. It would be impossible to measure how much greenhouse gasses are emitted by each pollution source as it would require the placing of measuring devices on every car exhaust and every chimney, etc. Instead a tax could be levied at source. Carbon dioxide emissions are related to the volume of fuel used which means that emissions can easily be taxed, by levying a tax proportional to carbon component of the fuel. This is the basis of the European Commission proposals that are modelled here. However this relationship does not apply for other greenhouse gasses such as sulphur dioxide. Other mechanisms are needed to reduce these such as tax incentives or regulations to have catalytic converters[6] installed in new cars or encouraging the reduction of fuel usage such as road pricing[7], differential car taxation, subsidising of public transport[8] or energy efficiency technology[9] such as simple measures like draft excluders. The impact of using taxation to reduce carbon dioxide will only be studied here.

The European Commission in 1991 proposed that taxation be imposed in order to maintain carbon dioxide emissions in 2000 at the 1990 levels and to reduce the reliance on non-renewable energy sources, valued at $10 per barrel. Revenues from this tax would accrue to the member states, allowing countries to reduce the reliance on distortionary taxation such as income taxes. The tax would have an income effect, raising the price of energy and also a substitution effect, substituting expenditure away from fuels with a high carbon component such as coal or peat and towards fuels with lower carbon components such as natural gas. It has however been impossible to reach agreement between the member states of the EU, with Britain especially being opposed to the Commission having a greater say in the field of taxation and others concerned about the economic costs. It was therefore agreed that decisions about carbon dioxide abatement should rest at the national level.

Britain's solution instead focused on increasing excise duties on motor fuels by 3% more than inflation per annum and by increasing the levels of VAT on domestic fuels. This however does not give any incentive to substitute away from fuels such as coal. Although it is likely Britain will achieve its objective of maintaining emmission levels in 2000 at 1990 levels, it will have been more due to economic recession and

---

[4] See Scott (1992) and O'Donoghue (1996).
[5] See Symons et al. (1994).
[6] These do not reduce carbon dioxide emissions however.
[7] See Smith (1995).
[8] Vary car taxes by engine size and age of car; bigger engines and older cars emit more greenhouse gasses.
[9] See Scott (1995) and Brechling and Smith (1994).

the privatised industries switching to gas from coal than from fiscal policy[10]. Likewise in Germany the closure of a lot of the energy inefficient and highly polluting plants in the East have also helped them to meet the EU targets. The ability of major countries to reach their emission targets without fiscal policy does not however eliminate the need for action to reduce carbon dioxide emissions. Economic growth after 2000 may lead to further increases in carbon dioxide emissions, so carbon taxation may be required as a policy instrument. It is for this reason the impact of carbon taxation will be modelled in Ireland.

4. Input-Output Analysis

Industries use fossil fuels both through direct production demand and indirect production demand. Direct production demand takes place when industries purchase fossil fuels for domestic use, for example heating or powering a fleet of trucks. Indirect consumption of fossil fuels occurs when industries purchase goods that have fossil fuel inputs into their production. In order to estimate emissions of carbon dioxide and the volume of energy consumed by Irish industrial sector, an input-output simulation analysis will be utilised. Leontief (1951) was the first to develop the methodology used in input-output analysis, which is overviewed in Chiang (1984). Input-output analysis in Ireland goes back to the sixties to work by Geary (1962, 1964) and Henry (1986), all of which is reviewed in detail Garhart and Moloney (1994). Similar analyses which have focused on carbon dioxide production, conducted internationally include Gay and Proops (1993) in the UK and Casler and Rafiqui (1993) in the USA.

Output in each sector has two possible uses; it can be used for final demand or as an intermediate input for other sectors. In an n sector economy, final demand for sector i's produce is denoted by $\mathbf{d_i}$ and the output of sector i by $\mathbf{x_i}$. Using standard assumptions, outlined in Chiang (1984), intermediate input from sector i into sector j is defined as $\mathbf{a_{ij}}\ \mathbf{x_j}$, where $\mathbf{a_{ij}}$, the input coefficients, are fixed in value. In other words, $\mathbf{a_{ij}}$ is the quantity of commodity i that is required as an input to produce a unit of output j. Output can therefore be seen as a sum of intermediate inputs and final demand, as follows:

$$x_i = \Sigma_j\, a_{ij}.x_j + d_i \qquad (4.1)$$

or in matrix terminology:

$$x = A.x + d \qquad (4.2)$$

Combining the output coefficients to produce an **(I-A)** *technology matrix* and inverting, *Leontief's inverse matrix,* L_{Dom} is produced, which gives the direct and indirect inter industry requirements for the economy:

[10] See Smith (1995)

$$x = L_{Dom}.d \qquad (4.3)$$

where

$$L_{Dom} = (I-A)^{-1} \qquad (4.4)$$

Equation 4.3 can be expanded to produced the following

$$x = d + Ad + A^2d + A^3d + A^4d + ... \qquad (4.5)$$

As **A** is a non-negative matrix with all elements less than 1, $\mathbf{A^m}$ approaches the null matrix as m gets larger, enabling us to get a good approximation to the inverse matrix. Equation 4.5, thus expands output per sector in to its components of final demand **d**; **Ad,** the inputs needed to produce d; $\mathbf{A^2d}$, the inputs required to produce **Ad**, etc. to produce the number of units of each output used in the production of a unit of final demand for each good.

5. The Data

The data used for this model are based on the 41 sector input-output table for Ireland produced by the CSO (1992). The most recent tables produced by the CSO, however are only for 1985 which means that the industrial structure described may be quite out of date. The economy has changed quite a lot since then, especially with regard to fuel use with the introduction of a coal powered electricity generating station at Moneypoint in Co. Clare as a source of domestic energy and for electricity generation.

Table 5.1 - Total Primary Energy Requirement 1980-1993 by volume (000 TOE)

YEAR	Coal	Peat	Oil	Natural Gas	Hydro	Other Renewables	Total TOE	Total CO_2
1980	732	1171	5614	459	71	N/A	8047	25639
1985	1054	1447	3890	1590	69	N/A	8050	25180
1990	2162	1358	4286	1446	59	110	9420	29787
1993	1947	1197	4936	1749	64	113	10007	30877
tCO2/TOE	3.7	4.34	3.01	2.07	0	0		

Table 5.1 indicates how the demand for different fuels has altered since 1980. Total demand has increased by 25% since the early/mid-eighties, but also the fuel mix has changed. Between 1985 and 1993 there has been a switch from peat to coal; in 1985 coal consisted of 13% of total fuel consumed, whereas peat consisted of 18%. These figures reversed in 1993, due to a significant increase in consumption of coal, entirely in electricity generation. Whereas consumption of coal almost halved in the industrial and residential sectors, electricity generation increased its consumption of coal from 38 TOE's in 1985 to 1429, 1000 TOE's in 1993[11], reducing the average carbon

[11] This was as a result of the opening of the large coal burning power station at Moneypoint.

dioxide emission per energy consumed[12]. However since 1980, coal and peat consumption increased from 23% to 31%. Nevertheless the average number of tonnes of carbon dioxide per TOE reduced over this period because of the increasing proportion of natural gas used in economy. Natural Gas has the lowest ratio of carbon dioxide to energy produced, half that of peat, and its consumption has increased substantially since 1980, due to the find off the coast of Kinsale. Since 1985, however, while the total consumption of gas has increased, the percentage of total energy supplied by gas has reduced[13]. Most primary fuels were used in electricity generation and oil refining, with residential, transport and industrial sectors being the next highest sectors.

Table 5.2 Energy balance 1985 (000 TOE)

	Power	Industry	Trans.	Resid.	Comm.	Agric.	Total TOE	Direct CO2 (Tonnes)
Coal	31	205	0	688	76	0	1000	3700
Peat	712	0	0	670	61	0	1443	6262
Oil	553	929	1718	295	287	94	3821	11516
Natural Gas	1288	217	0	55	37	0	1597	3305
Electricity	178	316	1	341	157	32	1025	0
Total	2762	1667	1719	1994	618	94	7861	24786

Source: Dept. of Energy, 1991.

The tables produced by the CSO provide information on the expenditure in £m of each input used to produce a £m of final demand. The input-output tables contain four sectors which measure fuels or energy[14]. These are the variables which are of principle interest. Nace category 9 was disaggregated into two new categories electricity and water and natural gas, which is a primary fuel.

BGE and ESB[15], which are monopoly suppliers of natural gas and electricity in Ireland, publish national aggregate figures for gas and electricity production. Subtracting these from the total output of nace sector 9, an estimate of the value of water service component of nace sector 9 is found to be about 17% of total. The ratio of electricity and gas output can be estimated across six aggregate economic sectors[16] by using energy consumption figures published by the Department of Energy(1994) and prices per TOE published by EOLAS (1994), which allows us to disaggregate the category. Nace 15 also contains other industries as well as primary energy sectors. These however have not been disaggregated, assuming instead that all Nace 15 inputs were peat fuels in the power and household sectors and that for all other sectors nace 15 inputs contained no peat fuel. The resulting matrix is the **x** matrix described in the last section. Dividing by total output, the **A** matrix was produced and using the

[12] Highlighting this point, energy consumption increased by 25% between 1985 and 1993, whereas carbon dioxide emissions only increased by 23%.

[13] The reserves of natural gas are quite limited and are due to run out in the next twenty years. However the opening of the gas interconnector between the UK and Ireland will allow Gas consumption to be maintained or increased.

[14] 3, Coal; 7, Oil; 9, Electricity/Water/Gas; 15, includes Peat.

[15] Bord Gais na hEireann(1986) and the Electricity Supply Board(1986).

[16] Power, Industry, Commerce, Transport, Residential and Agriculture sectors

expansion described in equation 4.4, the Leontief inverse matrix $\mathbf{(I-A)^{-1}}$ was constructed.

6. Modelling Carbon Dioxide and Energy Consumption

The direct and indirect emission of Carbon Dioxide per sector can now be measured. There are three sources of direct and indirect carbon dioxide emissions; inter-industry, final demand fuel consumption and indirect carbon dioxide emitted in the production of imports. Input output tables contain expenditures only, so the first objective, will be to produce two matrices **c** and **e** which contain the quantities of carbon dioxide and energy per £1000 fuel expenditure respectively.

These calculations are reported in table 6.1. Expenditures are taken from the input output table, **x** constructed in section 5, energy in TOE's are taken from the Dept. of Energy's energy statistics and carbon dioxide emissions are imputed. Peat and coal significantly more carbon dioxide for each pound of expenditure, at 24.6 and 44 tonnes of carbon dioxide per £1000 expenditure respectively than oil and natural gas at 9 and 9.9 tonnes per £ 1000 respectively.

Table 6.1 Ratios of carbon dioxide and energy to expenditure by fuel.

	Coal	Oil	Natural Gas	Peat
Expenditure (£m)	151	1267	335	142
TOE (1000's)	1000	3821	1597	1443
tCO2 (1000's)	3700	11518	3306	6263
TOE per £1000 fuel expenditure	6.64	3.02	4.77	10.13
tCO2 per £1000 fuel expenditure	24.56	9.09	9.88	43.97

A substantial source of carbon dioxide is fuels consumed in final demand. This consists of both domestically produced fuels such as gas and peat and imported fuels like oil and coal. Table 6.2 measures the direct and indirect emissions of carbon dioxide consumed by final demand. For the carbon dioxide emissions of imports, UK levels are assumed to be representative of average imported levels and are found in Gay and Proops (1993)[17].

Table 6.2 Fuels consumed in final demand

Sector	Total Final Demand[18] (£m)	Indirect CO_2 intensity (tCO_2/£m FD)	Direct CO_2 intensity (tCO_2/£m FD)	Total Direct Energy (TOE)	Total Direct CO_2 (1000 tonnes)	Indirect Carbon Dioxide (1000t)
Domestic						
Coal	1	1953	24559	9	32.91	3
Petroleum	138	9572	9093	416	1254.65	1321
Gas	80	7422	9878	455	792.57	596
Peat	72	1373	40224	670	2896.14	99

[17] Values for direct and indirect energy consumed are not included
[18] Note Total Final Demand includes changes in total stocks which is not reported here.

Imports						
Coal	75	1090	24559	968	1851	82
Petroleum	253	423	9093	2945	2305	107
Total	620	3558	14720	5463	9132	2207

Of primary interest to this paper is the inter-industry production demand for energy and carbon dioxide. Inter-industry direct and indirect domestic carbon dioxide emissions are the product of the carbon dioxide/fuel expenditure ratio matrix, multiplied by the direct fuel proportions times the domestic Leontief inverse matrix as follows[19]:

$$c'C.(1-A)^{-1} = c'C.(1 + A + A^2 + A^3 + A^4 + \ldots) \qquad (6.1)$$

C is a matrix containing the ratio of direct fuel expenditure to total output for each sector. There are four rows for each fuel type and 40 columns for each industrial input[20]. **E** is the corresponding matrix for energy consumption.

Imported goods have also emitted carbon dioxide in their production The values reported in Gay and Proops (1993) are the indirect carbon dioxide emissions per unit input. For our analysis, we need the imported carbon dioxide produced per unit of final demand however, for which we need a Leontief inverse matrix for imported goods. Although it is not published, it can be easily constructed; by multiplying the direct input of imports per unit output[21], $\mathbf{L_{Dom}}$ by the Leontief inverse matrix for the domestic economy:

$$L_{imp} = A_{imp}'. L_{Dom} \qquad (6.2)$$

Direct and indirect production demand of carbon dioxide is then produced as follows:

$$c_{imp}.L_{imp} = c_{imp}.A_{imp}'. L_{Dom} \qquad (6.3)$$

Table 6.5 outlines the inter-industry domestic and imported indirect and domestic direct carbon dioxide intensities. The values represent the quantity in tonnes of carbon dioxide per £m of final demand and are ranked from highest to lowest by total carbon dioxide intensity. Additional carbon dioxide intensities for final demand have not been included in this table.

Not surprisingly, the energy utilities have the highest carbon dioxide intensities. The production of electricity and petroleum have by far the highest carbon dioxide emissions per unit of final demand; nearly three times as high as the next highest, Gas. Amongst the utilities, direct production demand makes the highest contribution to the Carbon Dioxide intensity. The next most intensive carbon dioxide emitting sector are the heavy industrial and building sectors. Food processing sectors also have high carbon dioxide intensities; in fact three sectors have higher intensities than inland transportation. The final two types of sectors are light industries and services in that

[19] Energy consumption is estimated in the same way.
[20] Fuel expenditure comprises of both domestic and imported fuels.
[21] CSO(1989)

order. Unlike utilities which are mainly directly reliant on fossil fuels, virtually every other sector has a greater indirect carbon dioxide intensity. This is due to the influence of electricity. Only the transportation sectors have higher direct carbon dioxide production demand. Metal products and gas have the highest imported indirect carbon dioxide intensity. Although both light industry and services have on average low intensities, light industry tends to be predominantly more reliant on imported indirect carbon dioxide.

Table 6.4 looks instead at the total volume of carbon dioxide produced per sector. This table outlines therefore which industries contribute most to the greenhouse effect. The relative volume of carbon dioxide emission will relate to both the sector's carbon dioxide intensity, and also to the size of the industry. In this table, only those sectors that produce more than 2% of total carbon dioxide emissions are reported here. All other sectors have been aggregated together and form about 18% of carbon dioxide usage.

Table 6.3 Total Direct and Indirect Production Demand of CO_2 (million tonnes)

	Direct	Indirect
Inter industry domestic	7.28	7.82
Inter industry imported	0.00	4.71
Final demand domestic	4.98	0.00
Final demand imported	4.16	0.19
Total	16.41	12.71

Table 6.4 Total direct and indirect inter-industry CO_2 production

Nace Code	Industry	Quantity (1000 tonnes CO_2)	Percentage
53	Building & Construction	2102	10.6
17	Chemical Products	2053	10.4
9	Electricity/Water	1816	9.2
31	Meat/Meat Products	1357	6.9
7	Petrol Products	1376	6.9
33	Milk & Dairy Products	1310	6.6
35	Other Food Products	1150	5.8
23	Office Machines	876	4.4
15	Non Metallic Mineral Products	667	3.4
57	Wholesale/Retail Trade	604	3.0
81	General Public Services	595	3.0
41	Textiles/Clothing	541	2.7
37	Beverages	516	2.6
89	Non Market Health Services	485	2.5
59	Lodging/Catering Services	455	2.3
25	Electrical Goods	392	2.0
	Other Sectors	3511	17.7
	Total	19807	100

Table 6.5 Inter-industry carbon dioxide intensity in tCO2 per £m of Final Demand

Nace Code	Industry	Direct	Indirect	Indirect (from imports)	Total
07	Petrol Products/Natural gas	8302	1271	402	9975
09	Electricity/Water	6469	953	99	7522
10	Gas	2415	69	66	2550
03	Coal/Lignite/Briquettes	1657	296	76	2029
15	Non Metallic Mineral Products	847	526	342	1715
17	Chemical Products	678	313	461	1452
13	Metals and Ores	223	849	311	1384
53	Building & Construction	396	486	246	1127
35	Other Food Products	300	429	330	1060
37	Beverages	318	523	209	1051
33	Milk & Dairy Products	249	603	188	1040
61	Inland Transport	568	337	106	1010
59	Lodging/Catering Services	193	689	49	931
41	Textiles/Clothing	212	293	401	905
31	Meat/Meat Products	79	575	174	827
49	Rubber/Plastic Products	115	266	445	826
45	Wooden Products/Furniture	145	432	245	823
19	Metal Products (excl. mach.)	77	215	500	792
01	Agric/Forestry/Fishing	172	423	178	773
63	Maritime/Air Transport	416	227	63	705
43	Leather/Footwear	63	324	263	650
21	Agric./Industrial Machinery	56	163	405	624
27	Motor Vehicles	61	159	394	614
47	Paper/Printing Products	74	244	297	614
55	Repair/Recovery Service	52	243	267	561
79	Other Market Services	136	367	56	559
69	Credit & Insurance	21	442	71	535
29	Other Transport Equipment	47	109	341	498
51	Other Manufacturing Products	44	136	316	496
25	Electrical Goods	37	125	327	490
89	Non Market Health Services	141	248	90	480
39	Tobacco Products	45	211	222	477
23	Office Machines	16	90	360	466
81	General Public Services	137	262	52	451
57	Wholesale/Retail Trade	79	324	40	444
67	Communication Services	25	318	53	397
65	Auxiliary Transport	98	253	36	387
71	Business Services	86	168	22	277
73	Renting of Immovable Goods	0	184	91	275
93	Other Non Market Services	36	117	18	172
11	Radioactive Material & Ores	0	0	0	0
05	Products of Coking	0	0	0	0

7. Impact of a Carbon Tax on Industrial Sectors

Direct and indirect production demand for energy and carbon dioxide have been calculated. The impact of an energy tax on costs can now be estimated. In this paper two types of tax will be modelled:

- A Carbon/Energy Tax as proposed by the European Commission.
- An increase in Excise taxation.

The European Commission proposed that tax be imposed on fuels with half the tax levied on the carbon content and half on the energy content of the fuel. A tax the equivalent to $10 per barrel of oil was proposed and can be transformed into pounds per TOE or tonne of carbon dioxide emissions as follows:

Table 7.1 Calculating the cost of a $10 carbon tax per TOE and tCO_2

Given:
7.33 barrels of Oil per TOE
0.854 tonnes of Carbon per TOE
3.66 tonnes of Carbon Dioxide per tonne of Carbon
$5 tax per barrel = IR£3.19 tax per barrel
Then:
Energy component of tax = IR£23.38 per TOE
Carbon component of tax = IR£7.47 per tonne of Carbon Dioxide

Source: Scott (1992)

A $10 per barrel of oil tax would therefore imply a tax with a carbon component of £7.47 per tonne of carbon dioxide emitted and an energy component of £23.38 per TOE. In other words a carbon/energy tax of this form would cause the price of a gallon of petrol to increase by 6% and a 40kg bag of coal to increase by 17%[22]. An increased excise tax was also modelled. This was done by increasing the price of fuels by the same percentage regardless of carbon content to produce the same revenue as the carbon taxes modelled.

Energy taxes would put pressure on prices, both through direct consumption and through increases in prices of inputs. It shall be assumed that producers pass the full weight of the tax on to consumers of their output. In addition in the short term no cross substitution of fuels will be assumed to take place, an assumption often made in input-output modelling. It is likely to be true in the short term, but in the long term, production processes would adjust to be more efficient in fuel and energy use as a result of the tax. Two scenarios will be considered with regard to the price elasticity of fuels. The first is a 'day after' scenario, where no reduction in demand is modelled; the consumer will consume as much fuel as before and pass the full price onto the consumer. The second scenario assumes as Fitzgerald and McCoy (1992) did, a price elasticity of energy to be -0.3. In other words an increase in the price of a fuel by 10% would lead to a decrease in the demand of fuel by 3%.

[22] Scott (1992). Figures refer to 1991 prices.

We shall first look at the '*day after*' effect of a carbon/energy tax, where firms do not reduce their energy expenditures. The annual revenue from the tax would have been £365m in 1985. In addition total cost to industry and consumers would increase by a further £75m as we have assumed that a tax would be introduced at a multinational level.

A '*day after*' analysis assumes no reduction in carbon dioxide. However if an energy elasticity of -0.3 is assumed, then carbon dioxide would decrease by about 7.1% and revenue from taxation would drop by £30m. If instead an extra excise tax was levied, valued at 20%[23] of fuel expenditure, carbon dioxide emissions would decrease by only 5.8% and revenue by about £20m. Excise taxation therefore reduces carbon dioxide emissions by about four fifths the amount reduced as a result of carbon taxation.

Table 7.2 The impact carbon/energy and excise taxes after allowing for an energy elasticity of -0.3

	Carbon/Energy Tax			*Excise Tax*		
	Inter Industry	FD	Total	Inter Industry	FD	Total
total tax revenue	£215m	£121m	£336m	£216m	£128m	£344m
reduction in expenditure on fuels	£57m	£40m	£88m	£73m	£36m	£109m
percentage reduction in expenditure	4.5%	6.4%	4.7%	5.8%	5.8%	5.8%
reduction in CO_2 (million tonnes)	0.9	0.8	1.7	0.9	0.5	1.4
percentage reduction in CO_2	5.9%	9.1%	7.1%	5.8%	5.8%	5.8%

Increased revenues from environmental taxation can allow for a reduction in other, more distortionary forms of taxation such as taxes on labour. Fitzgerald and Mc Coy (1992) in their macro study of the implementation of carbon taxation in Ireland analysed the effect of using revenues from a carbon tax to reduce employer social insurance contributions. They found that a carbon tax/social insurance contribution reform like this would have a positive effect on the economy, increasing GDP, reducing the debt ratio and increasing employment in the medium term. The same will be done here, assuming that all the revenue from the tax would go towards reducing social insurance contributions and thus labour costs.

Figures 7.1 and 7.2 highlight the net impact on costs faced by industrial sectors, described in table 7.4, as a result of these reforms[24]. Figure 7.1 graphs the net change in costs in as a percentage of final demand as a result of a revenue neutral carbon tax. It is interesting to note that most sectors would reduce their cost per unit final demand. Sectors with higher labour costs than energy costs, would therefore be net beneficiaries of a reform like this. Increasing costs, tends to be concentrated in energy utilities and heavy industries, and also in food processing.

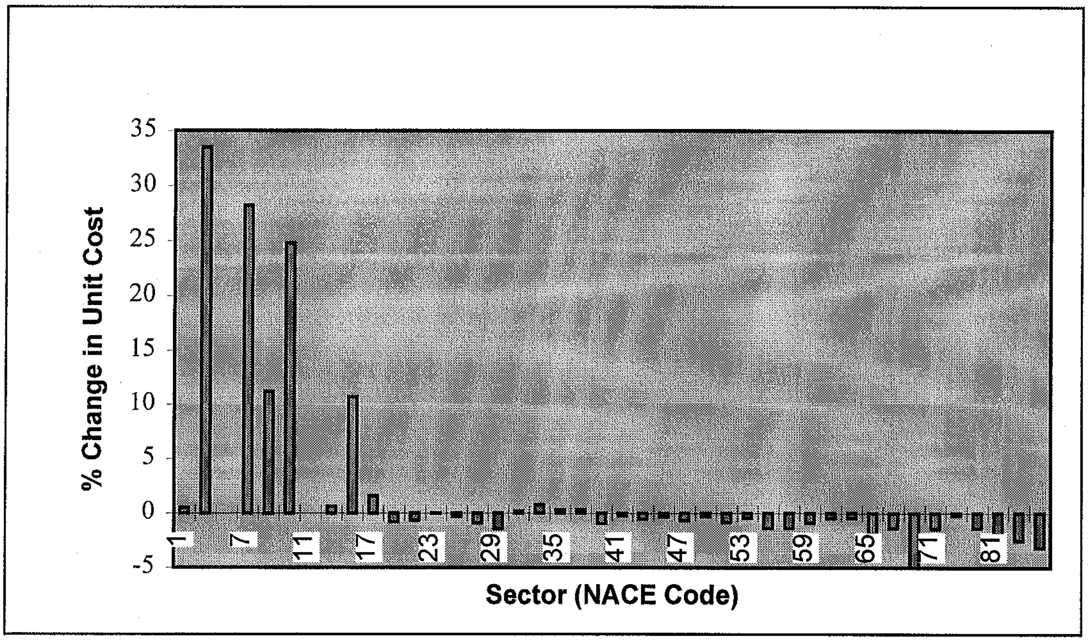
[23] Total tax revenue is £377m and total expenditure on fuels is £1886m

[24] Increase in costs of fuels consumed by final demand is not included in these charts.

Table 7.3 Description of NACE code sectors

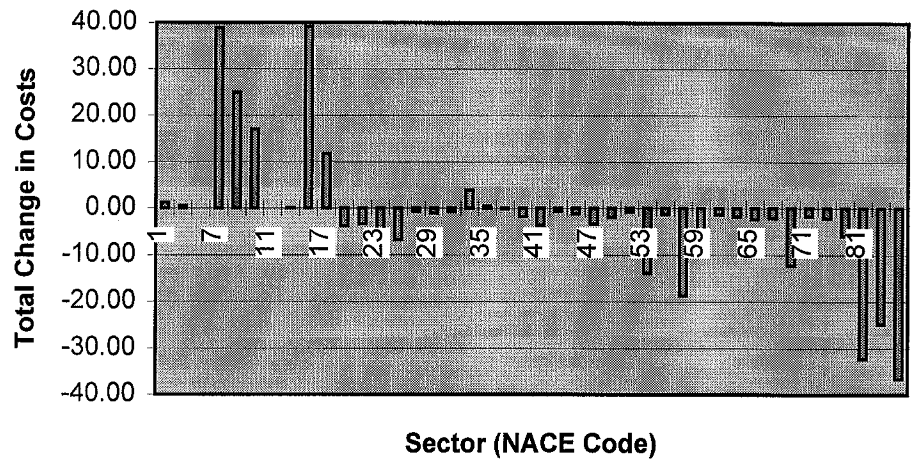
Nace Code	Sector	Nace Code	Sector	Nace Code	Sector
01	Agric/Forestry/Fishing	27	Motor Vehicles	55	Repair/Recovery Service
03	Coal	29	Other Transport Equip.	57	Wholesale/Retail Trade
05	Products of Coking	31	Meat/Meat Products	59	Lodging/Catering Services
07	Petrol Products	33	Milk & Dairy Products	61	Inland Transport
09	Electricity/Water	35	Other Food Products	63	Maritime/Air Transport
NG	Natural Gas	37	Beverages	65	Auxiliary Transport
11	Radioactive Material	39	Tobacco Products	67	Communication Services
13	Metals and Ores	41	Textiles/Clothing	69	Credit & Insurance
15	Non Metallic Mineral Prod.	43	Leather/Footwear	71	Business Services
17	Chemical Products	45	Wood Prod./Furniture	73	Rent Immovable Goods
19	Metal Products	47	Paper/Printing Prod.	79	Other Market Services
21	Machinery	49	Rubber/Plastic Prod.	81	General Public Services
23	Office Machines	51	Other Manufacturing Prod.	89	Non Mkt. Health Services
25	Electrical Goods	53	Building & Construction	93	Other Non Mkt. Services

Figure 7.1 Net effect of carbon/energy tax/social insurance contribution reform by NACE sector (as a percentage of Final Demand)



The actual change in costs is graphed in figure 7.2; as one would expect, reductions in costs would accrue to the service sector. There would however be a reduction in competitiveness amongst exporting sectors. Introducing a carbon tax would increase costs by £146 million. This would be greatly reduced, down to £29 million, if all revenues went towards reducing labour costs. However these figures are small when total exports of £10.3 billion in 1985, are considered.

Figure 7.2 Net effect of carbon/energy tax/social insurance contribution reform by NACE sector (in £m of Final Demand)



Environmental commentators have suggested that a carbon tax could replace income taxation in Ireland, however this has been found not to be possible. In 1985, total income tax receipts were £2163m[25]. A tax of $59 per barrel of oil equivalent would be required to produce this amount of revenue, in other words an increase in fuel costs of over 115%. However this is assuming that energy consumption would continue at the same level. If an energy elasticity of -0.3 is assumed, then fuel consumption would decrease by about 35%, thereby reducing the total revenues. In our analysis, maximum revenue would occur at tax rate of $63 per barrel of oil, but yet would only produce revenues of just over half those produced by income taxation.

8. Conclusions

An input output analysis was carried out on the Irish economy to investigate the direct and indirect production demand for carbon dioxide and energy and to model the impact of energy taxation. Estimates for the amount of carbon dioxide were estimated per unit of fuel expenditure and per unit final demand. Using Leontief inverse matrices for domestic and imported inputs separately, direct and indirect carbon dioxide demand were modelled. Unlike previous studies, imported goods were included in the analysis.

It was found that energy utilities, heavy industry and food sectors had the highest direct and indirect output of carbon dioxide per £ million final demand. In addition for all sectors except for the utilities and transport sectors, indirect emissions of carbon dioxide were larger than direct emissions.

[25] CSO (1992) 1985 input-output tables

As carbon dioxide emissions are expected to increase by about 25% over the course of the1990's, two tax instruments were modelled to try to reduce emissions. One was a carbon/energy tax proposed by the European Commission valued at $10 per barrel of oil equivalent. The other tax was an increase in excise taxes on fuels.

Revenue of £365m was found when the $10 carbon tax was modelled with an energy elasticity of 0. In this *'day-after'* scenario, carbon dioxide does not decrease. However when the more realistic elasticity of -0.3 was used, carbon dioxide emissions were found to decrease by 7.1%. Revenue also decreased by £30m. On the other hand when an excise tax of 20% of fuel price was modelled, carbon dioxide emissions decreased by about four fifths of the amount reduced by a carbon tax, illustrating that carbon taxes are a more effective means of reducing carbon dioxide than excise taxes. In addition in the long run when fuel substitution comes into play, the difference in carbon dioxide reduction between carbon and excise taxes is likely to be greater. Finally it was found that it would not be possible to replace income taxes by carbon taxes.

References

Brechling V. and S. Smith, 1994. *"Household Energy Efficiency in the UK",* Fiscal Studies, vol. 15, no. 2, pp 44-56.

Casler, S.D. and A. Rafiqui, 1993. "Evaluating Fuel Tax Equity: Direct and Indirect Distributional Effects", *National Tax Journal*, Vol. XLVI, pp 197-205.

Chiang, A.C., 1984. *Fundamental Methods of Mathematical Economics*, McGraw-Hill.

Cline, W.R., 1991. "Scientific Basis for the Greenhouse Effect", *The Economic Journal*, Vol. 101, pp 904-919.

Convery, F., 1994. "" in J. Feehan (ed.), *Climate Variation and Climate Change in Ireland*, ed. John Feehan, UCD Environmental Institute.

Cropper, M. L., and W. E. Oates, 1992. 'Environmental Economics: A Survey', *Journal of Economic Literature*, Vol. XXX, pp. 675-740.

CSO, 1992. *Input Output Tables for 1985, Volume 1,* Dublin: Central Statistics Office.

DEPARTMENT OF ENERGY, (1991). *Energy Balances*. Dublin: Stationery Office.

EOLAS, 1990. *Comparison of Useful Energy Costs.* EOLAS

EPA Corinair 1990. Emissions Estimates Report

Fitz Gerald J. and D McCoy, 1992. "The Macroeconomic Implications for Ireland", in J. Fitzgerald and D. McCoy (eds.) *The Economic Effects of Carbon Taxes*, Dublin: The Economic and Social Research Institute, Policy Research Series Paper No.14.

Garhart, R. and R. Moloney, 1994. *Irish Input-Output: A Survey.* UCC: Dept. of Economics Working Paper Series 94-5.

Gay, P.W. and J.L.R. Proops, 1993. "Carbon Dioxide production by the UK Economy: An Input-Output Assessment", *Applied Energy,* Vol. 44, 113-130.

Geary R.C., 1962 An Experimental Input-Output Decision Model for Ireland, ESRI Memorandum Series 11.

Geary, R.C., "Towards an Input-output Decision Model for Ireland", Journal of the Statistical and Social Inquiry Society of Ireland, Vol. 21, no. 4

Henry E., S. Scott, 1977, *" A National Model of Fuel Allocation- a prototype"*, Dublin: ESRI General Research Series Paper no. 90.

Leontief W.W., 1951. *The Structure of American Economy 1919-1939,* 2nd. ed. Oxford University Press.

O'Donoghue, 1996 forthcoming. 'The direct and indirect of impact of carbon taxes on the Irish income distribution'. *ESRI Working Paper.*

Pearce D., 1991. "The role of Carbon Taxes in Adjusting to Global", *Economic Journal* Vol. 101, pp 938-948.

Poterba, J.M., 1991. "Tax policy to combat global warming: on designing a carbon tax", in R. Dornbusch. and J.M. Poterba (eds.), *Global warming: economic policy responses*, MIT Press.

Scott, S., 1992. 'Theoretical Considerations and Estimates of the Effects on Households', in J. Fitzgerald and D. McCoy (eds.) *The Economic Effects of Carbon Taxes*, Dublin: The Economic and Social Research Institute, Policy Research Series Paper No.14.

Scott S., 1995. *"Social Welfare Fuel Allowances...to Heat the Sky?"*, Economic and Social Research Institute Seminar, January, Dublin.

Smith, S., 1995. *'Green' Taxes and charges: Policy and Practice in Britain and Germany.* London: IFS

Symons E., J. Proops, P. Gay, 1994, *"Carbon Taxes, Consumer Demand and Carbon Dioxide Emissions: A Simulation Analysis for the UK"*, Fiscal Studies, Vol. 15, no. 2, pp19-443.