CARBON DIOXIDE, ENERGY TAXES AND HOUSEHOLD INCOME

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November 1997

Working Paper No. 90

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Abstract

This paper examines the impact of a carbon tax on the income distribution in Ireland using the 1987 Household Budget Survey. Previous studies have focused on the direct impact of the carbon tax on expenditures on domestic fuels. This study however, drawing on previous work expands the analysis to cover the indirect impact of carbon taxes on other household purchases. A direct and indirect tax would have a less regressive effect on the income distribution than a simple direct tax on household fuel expenditures. A consumer demand system was in addition used to determine the behavioural response to a number of reforms, including a tax only on industrial fuel purchases and a revenue neutral direct and indirect tax, where revenues were redistributed via a flat payment.

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1. Introduction[1]

This paper will examine the impact on the Irish income distribution of implementing a carbon tax. A carbon tax has been proposed by the European Commission to reduce the emissions of carbon dioxide which contribute to the greenhouse effect. 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. 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.

Scott (1992) looked at the direct fuel and energy expenditure by households and assessed the distributional effect directly caused by a carbon tax. Indirect expenditure was also partially examined as the direct fuel inputs of electricity were included in the distributional analysis. She found that a carbon tax directly would have a very regressive effect on the income distribution. However a carbon tax would also have an indirect impact on the income distribution. Increases in carbon based products would also have an impact on the prices of other goods which have carbon based products as input. This would indirectly feed into increased costs for other household purchases. A previous paper (O'Donoghue, 1997) has simulated the direct and indirect production of carbon dioxide by industrial sector using an input-output analysis. Using these figures for purchases of domestic products and services and figures supplied by Gay and Proops (1993) for imported goods and services, the carbon dioxide indirectly produced by households can be modelled and as a result the indirect effect of a carbon tax can be simulated. Published tables of expenditure by gross income decile, taken from the 1987 Household Budget Survey (HBS) are used in this analysis. For the purposes of this study, the carbon tax is assumed to be passed entirely on to the consumer.

In this paper some background information about global warming will be discussed in section 2. The economic rationale for introducing a carbon tax will be dealt with in section 3. Section 4 will describe the expenditure on fuels by income decile. Section 5 outline the main features of the expenditure model and investigate the first round impact of a tax. Section 6 will discuss the potential behavioural response to this policy change. A number of revenue neutral policy experiments will be analysed in section 7. Section 8 will discuss some brief conclusions.

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*,

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[1] This paper is a draft document and should not be quoted without the author's permission. The author is grateful to Sue Scott, Hitoshi Hyami and Jonathan Köhler for comments. All errors remain the responsibility of the author.

Methane (CH_4), carbon dioxide (CO_2), chlorofluorocarbons (CFC's) and Nitrous Oxide (N_2O). Increases 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^{o}C. 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^{o}C. per decade over the next century if no remedial action were taken due to the rapid growth in GHG's 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 (European Commission, 1992). In the European Union, Ireland comes second after the Netherlands as a source of greenhouse gasses per capita (Convery, 1994), 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.

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 changes. An optimal tax would be set so as to reduce pollution to the point where the marginal social cost of pollution and the marginal abatement cost 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, Fitz Gerald 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.

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 issues 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[2] 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 is 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.

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

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

can easily be taxed, by levying a tax proportional to carbon component of the fuel. This is the basis of the 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[3] installed in new cars or encouraging the reduction of fuel usage such as road pricing(Smith, 1995), differential car taxation, subsidising of public transport[4] or energy efficiency technology(See Scott, 1995 and Brechling and Smith 1994) 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[5]. 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 emission levels in 2000 at 1990 levels, it will have been more due to economic recession and the privatised industries switching to gas from coal than from fiscal policy (Smith 1995). Likewise in Germany the closure of many 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. Energy Usage Across the Income Distribution

Taxation resulting from fuels consumed directly by households is the largest part of the carbon tax a household would face from direct and indirect sources. As we wish to

[3] These do not reduce carbon dioxide emissions however.

[4] Vary car taxes by engine size and age of car; bigger engines and older cars emit more greenhouse gasses.

[5] This tax has been modelled in this paper. However as the difference between the Energy tax and the Carbon tax is negligible in Ireland because of no nuclear power, we shall simply model a carbon tax.

investigate the distributive effect of an energy tax, we shall look first at the level of expenditure on fuels across the income distribution.

The data used comes from the 1987 Household Budget Survey (HBS) (CSO, 1989) which has a sample size of 7700. This is a survey of households' spending characteristics which is carried out every 7 years. The HBS unfortunately is not available in microdata form. We have instead used tabulations taken from the Survey.

There are a number of problems associated with this data. Firstly as the micro data is not available we have to rely only on 10 average households. These households represent no actual households and ignore most of the variation found in the expenditure patterns of households. Another problem is the actual definition of income; gross current income. This measure takes no account of a households actual living standard which is disposable income, or income after taxes and benefits. Another issue is the size of the household. A better measure of living standards for this analysis would be disposable income equivalised for household size and the economies of scale of living together.

The deciles are based on current income, which takes no account of long term living standards. Expenditure is likely to be more highly related to long term income patterns than current ones, as expenditure can be smoothed over the lifetime through borrowing or lending. Poterba (1991) found that a carbon tax would be less regressive if a lifetime income concept is used rather than current income. This is as a result of income differences over the life cycle and unpredictable income variations such as short term unemployment or illness.

Measurement error is another issue. Income is subject to understatement in income surveys and expenditure patterns are highly seasonal. In addition expenditure of certain items such as alcohol and tobacco tends to be understated. Grouping of households can be used to eliminate the effect of seasonality. Poterba found that a carbon tax would be far more regressive if households were ranked by income than by expenditure in the US. Smith (1992) found that the distinction between income and expenditure to be less in the UK.

Table 1 outlines the average household expenditure on 13 sectors by each gross income decile. Housing costs and expenditures on durables have not been included here as it is assumed that their expenditure would not vary as a result of a carbon tax. Expenditure on household fuels of all expenditure classes is the most similar across income deciles, followed by Tobacco and Food. As we can see in table Z.1, poorer households spend proportionally nearly twice as much on fuels as richer households as a proportion of their total expenditure. This distinction is most noticeable in the budget share of domestic fuel and energy where for the poorest decile is three times that of the top income decile. The budget share of motor fuel, on the other hand rises over the income distribution.

The definition of living standard used greatly affects the proportion of expenditure on fuels. If disposable income is used, lower deciles have far higher fuel expenditure shares than if expenditure is used to calculate the budget share. This is due to the fact that especially in the lowest deciles, average household expenditure tends to be higher than average disposable income. This effect is not as strong at the top and is reversed in the very top decile.

Conniffe and Scott (1990) investigated the income elasticity of domestic energy usage and found that oil had a much higher income elasticity than other domestic fuels. As oil has lower CO_2 components than other domestic fuels, most notably coal and turf, this would indicate that in addition to the lower budget shares, higher deciles use less polluting fuels. Scott (1992) illustrates this point graphically, showing that the poorest gross income decile emits about 10% more CO_2 per TOE than the highest decile. Smith (1992), in investigating the consumption patterns of fuels in six EU countries, found that Ireland had the highest differential in budget share on energy expenditure of the six. The proportion of expenditure spent on energy is however not related to the employment category of the head of household; employees, retired and the unemployed having similar budget shares. Retired and unemployed households have much higher budget shares of domestic fuel.

Table 1 Aggregated Weekly Expenditure before Carbon tax

Decile	1	2	3	4	5	6	7	8	9	10
Beer	1.91	2.94	4.32	5.48	7.93	8.48	9.08	10.51	12.18	18.17
Wine	0.09	0.16	0.15	0.23	0.36	0.32	0.57	0.78	1.08	2.37
Spirit	0.54	0.90	1.01	0.92	1.40	1.41	1.69	2.37	3.21	4.58
Food	23.35	31.86	40.68	48.43	53.85	59.35	63.62	69.58	77.46	94.40
Fuel	8.91	11.11	12.46	13.81	13.72	13.95	15.48	15.57	17.04	18.48
Clothing	3.14	4.33	7.64	9.24	12.51	14.81	16.54	20.67	26.28	35.28
Transport	2.61	2.85	4.74	7.08	9.46	13.13	14.80	17.39	19.81	32.25
Service	12.19	16.09	20.85	35.11	37.65	49.53	62.74	76.61	99.17	146.87
Petrol	1.99	3.20	4.06	6.42	8.84	9.42	12.34	14.20	16.63	19.26
Tobacco	3.37	5.60	6.61	7.85	8.52	8.02	8.29	7.85	8.24	8.68
Other	6.83	9.07	11.77	15.49	15.97	19.62	22.24	29.21	30.39	36.61
Total	70	96	124	164	187	220	253	297	353	466

In comparing the household budget surveys of 1980 (CSO, 1984) and 1987(CSO, 1989), it was found that the budget shares of total fuel expenditure has not changed very significantly across the income distribution over this time period. Since 1987 total household energy consumption has decreased by about 10%, with the domestic fuel mix shifting towards gas, oil and electricity at the expense of coal (Dept. of Energy, 1994).

Table 2 Fuel/Energy Expenditure across the Income Distribution in 1987

Decile of Gross Income	Average Expenditure	Budget Share of Domestic Fuel (%)	Budget Share of Motor Fuel	Budget Share of total Fuel Expenditure	Total Fuel Expenditure as a % of Total Expenditure	Total Fuel Expenditure as a % of Disposable Income
1	70.05	12.1	2.8	14.9	14.9	22.7
2	96.30	11.0	3.3	14.3	14.3	18.2
3	123.73	9.5	3.2	12.7	12.7	15.4
4	164.02	8.1	3.8	11.9	11.9	15.2
5	187.32	7.0	4.6	11.6	11.6	14.1
6	220.25	6.1	4.1	10.2	10.2	12.2
7	253.49	5.9	4.8	10.7	10.7	12.1
8	297.00	5.1	4.7	9.8	9.8	10.8
9	352.88	4.7	4.6	9.3	9.3	9.9
10	465.93	3.9	4.1	8.0	8.0	7.5
Average	223.08	6.3	4.2	10.5		

Source: CSO (1989)

5. Sources of Carbon Dioxide

Figure 1 outlines the direct and indirect sources of carbon dioxide used by final demand. We are in particular interested in the household sector. Households directly produce carbon dioxide when they burn fuels for cooking and heating etc. Fuels can be either domestically produced such as natural gas or peat or imported such coal and oil products. Households also indirectly produce carbon dioxide because other goods and services consumed by households will often have direct fuel inputs into their production. In addition goods purchased by households, will in turn have had other goods as input which will have had fuel inputs. Equation 1 describes these sources of carbon dioxide, direct production of carbon dioxide from fuels burnt by households and the direct and indirect inputs of fuels used by purchased by households, where C_{Dir} is the direct carbon dioxide amounts per unit of domestic fuel expenditure, $C_{D,\ inp}$ is vector of direct carbon dioxide inputs for household fuel and other good expenditures and $C_{I,\ inp}$ is vector of indirect carbon dioxide inputs for household fuel and other good expenditures.

(1) $$\text{Total } CO_2 = \text{Fuel} * (C_{dir}) + (\text{Fuel} + \text{Goods})* (C_{D.inp} + C_{I.inp})$$

As an investigation of the impact of a fiscal instrument on pollution control, we are interested in two points; the revenue from the taxation and the reduction in carbon dioxide. As a small open economy, Ireland is highly reliant on trade and as a result much of the goods used by households and the inputs of domestically produced goods will be imported. This will impact on where the tax is levied. In this paper we shall assume that the tax is levied where the fuel is burnt. Therefore for example fuel used as an input in an oil refinery will only be taxed when it is burnt to produce energy[6]. So for example if the fuel is refined in Wales, but burnt in Ireland, the tax will be levied in Ireland. We must therefore distinguish between where the product was

[6] O'Donoghue (1997) used the assumption that the tax was levied when the fuel was first used as an input in Ireland.

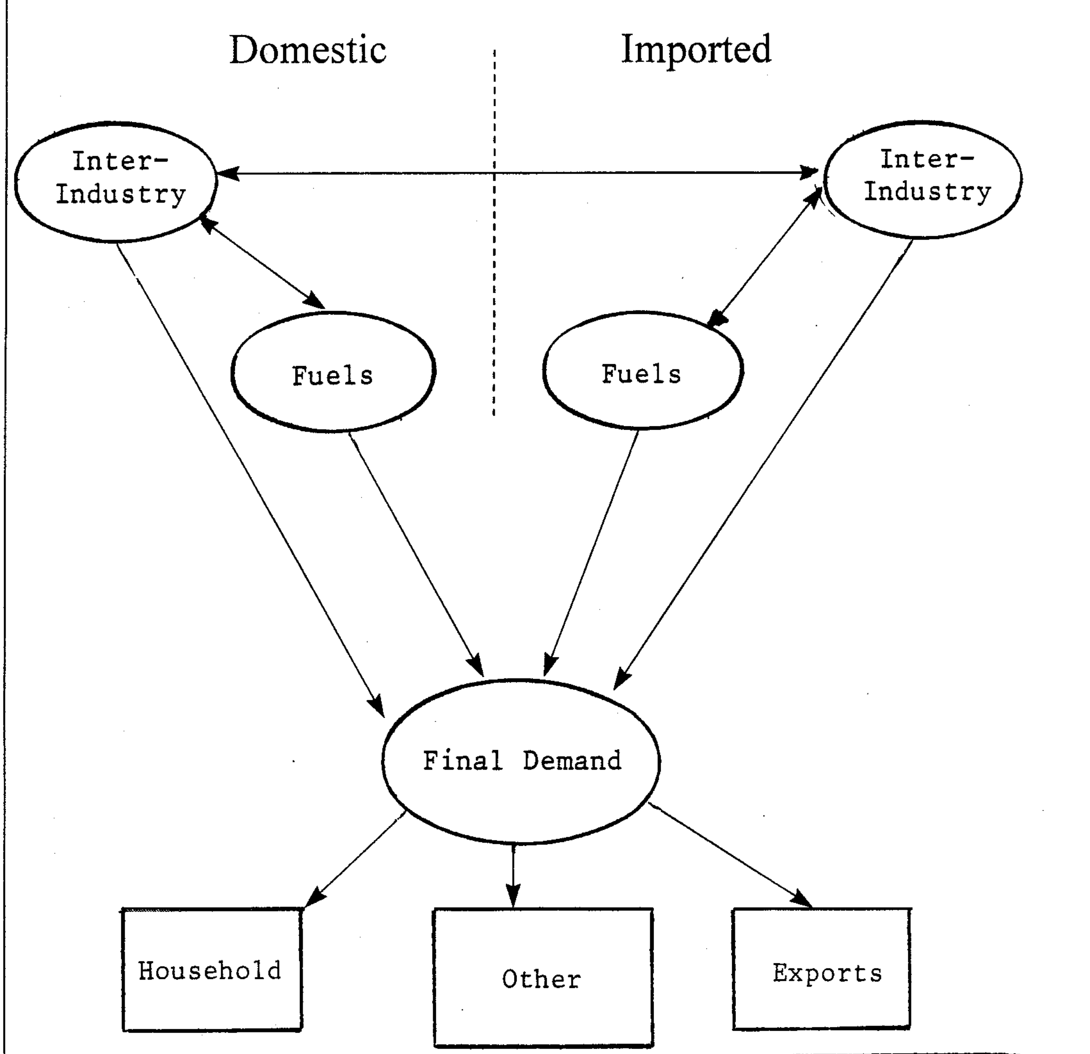
consumed and where the carbon dioxide was produced. For example fuel burnt as an input for an imported good will be taxed where the fuel was burnt (abroad). However, because in this paper it is assumed that the tax is fully incident on the final consumer the tax will be paid by the consumer in Ireland. Thus taxes will be levied at the source of pollution and paid at the source of consumption. Carbon dioxide used in the production of imported goods will raise revenue in the country of production, but will be fully passed on to the consumer in the final destination of purchase as outlined in equations 2 and 3 below. As the input-output structure of Irish produced goods cannot be assumed to be representative of all goods consumed in Ireland, we incorporate the imported sector in this model. This is an advance on analyses of this type as previous analyses (Symons et al, 1994 and Casler and Rafiqui, 1993) have assumed that all goods have produced and consumed at home.

(2) Total Tax Revenue = Carbon Tax * $(CO_{2\ Export} + CO_{2\ Household} + CO_{2\ Other})$

(3) Total Cost = Carbon Tax * $(CO_{2\ Import} + CO_{2\ Household} + CO_{2\ Other})$

Figure 1

Direct and Indirect Sources of Carbon Dioxide and Energy



On the basis of the O'Donoghue (1997) analysis applied to the 1985 input-output tables, Ireland is a net loser from the carbon tax before the revenue is redistributed. These tables show Ireland having a trade deficit which by the 1990's had become a large trade surplus. Imports were found to have a carbon tax per unit cost of 32% higher than exports. This is as a result of Ireland's reliance on imported manufactured goods, with high direct and indirect fuel inputs, such as chemical products, office machinery and metals. Ireland's largest source of revenue from the carbon tax placed on exported goods came from dairy and meat processing and from chemicals.

Another way of breaking down the consumption of carbon dioxide is through the type of fuel used. Different fuels produce different quantities of carbon dioxide per unit energy. These are outlined in table 3. Peat when burnt produces the most carbon dioxide per unit of energy at 4.34 tons per Ton of Oil equivalent. Natural Gas is the most efficient in terms of pollution producing less than half as much carbon dioxide as peat. As the tax levied will be proportional to the level of carbon dioxide produced, the type of fuel used in production and consumption will have a significant bearing on the amount of tax charged.

Table 3 Carbon Dioxide production per unit Energy

	Coal	Peat	Oil	Natural Gas
tCO_2/TOE	3.7	4.34	3.01	2.07

6. Description of the Expenditure Model

In this section, the expenditure model is described. The method of calculation of the tax is also described and the first round distributional impact of the carbon tax is investigated. Tables chronicling the average expenditure on each of 97 types of goods and services per gross income decile form the core of the model. The carbon dioxide component of each good and service purchased are modelled first. The indirect component is then simulated using the results of input-output analyses. Once direct and indirect carbon dioxide component have been modelled, the value of the carbon tax by consumption group and decile can be estimated.

The estimates of the direct carbon dioxide component used here has been calculated in Scott (1992), using the fuel expenditures described in the Household Budget Survey. O'Donoghue (1997) has produced figures for indirect carbon dioxide component of domestically produced goods and services. Gay and Proops (1993) has produced estimates for the UK which are assumed to be representative of Irish imports because the bulk of Irish imports come from Britain. This indirect carbon dioxide figures in O'Donoghue and Gay an Proops are at the level of industry (NACE code sectors) and have had to be transformed to find the indirect carbon dioxide production of each expenditure sector.

The imported sector was incorporated by breaking up household expenditures into domestically and foreign produced goods. Import weights taken from CSO (1989) were used for each good and service type and were assumed to be constant across household group. Indirect carbon dioxide estimates from O'Donoghue[7] were then applied to the domestic goods and from Gay and Proops to the foreign produced goods. Applying these estimates of indirect carbon dioxide per £ of expenditure to the average expenditure per income decile and adding the direct carbon dioxide produced through the use of fuels, the average direct and indirect carbon dioxide production can be found per decile. The distribution of direct and indirect carbon dioxide production in tonnes of Carbon Dioxide per annum is outlined in table 4. Direct carbon dioxide production forms a decreasing proportion of total carbon dioxide production amongst richer households, varying from about 70% in the bottom decile to around 50% for the top decile. This is not surprising due the size of expenditure on household fuels as a proportion of total expenditure amongst the lower deciles.

Table 4 Average Carbon Dioxide Emissions per household by Gross Income Decile (tCO_2)

Decile	1	2	3	4	5	6	7	8	9	10
Direct CO_2 per annum	5.8	7.1	8.5	9.7	9.7	9.2	11.0	10.7	12.1	12.3
Direct and Indirect CO_2 per annum	8.2	10.3	12.4	14.5	15.1	15.3	17.9	18.6	21.0	23.6

Once the direct and indirect carbon dioxide produced per unit of expenditure is calculated, the level of the carbon tax can be imputed. O'Donoghue (1997) describes how the carbon tax of IR£14.94 per tonne of carbon dioxide is calculated. Table 5 describes the increase in prices per expenditure group due to this tax. The largest increase in prices are in fuels at about 18.5% for domestic fuels and about 7.7% for motor fuels. Clothing and transport are the next in size with increases of just over 1%. All other sectors had increases of less than 1%.

Table 5 Percentage direct and indirect increase in prices of consumption goods due to Carbon tax

Consumption Good	Percentage increase in price
Beer	0.98
Wine	0.98
Spirit	0.98
Food	0.91
Fuel	18.70
Clothing	1.44
Transport	1.38
Service	0.28
Petrol	7.68
Tobacco	0.59
Other	0.68

Table 6 below outlines the first round impact of a carbon tax before any adjustment in expenditure. The values represent carbon tax as a proportion of total expenditure by decile. The carbon tax has been split up into that payable as a result of direct

[7] These figures include indirect carbon dioxide of from imported inputs for domestically produced goods and services.

expenditures on fuels and the indirect impact of the tax resulting from carbon inputs. The direct impact of the tax is quite regressive, with the tax being three times as high as a proportion of expenditure in bottom decile than the top decile. The indirect impact of the tax is virtually equal across the gross income distribution. Combining the two produces a less regressive impact on the income distribution; the bottom decile now pay 2 times as much as the top decile as a proportion of their expenditure.

Table 6 First round impact of carbon tax (Carbon Tax as a proportion of expenditure)

Tax as % of expenditure:	1	2	3	4	5	6	7	8	9	10
Indirect	1.04	1.03	1.02	0.97	0.97	0.95	0.92	0.90	0.88	0.85
Direct	2.29	2.03	1.91	1.65	1.46	1.17	1.21	1.01	0.97	0.75
Total	3.33	3.06	2.93	2.62	2.42	2.12	2.13	1.91	1.85	1.60

7. Behavioural Change

The estimates for the tax levied in the above case is purely an upper bound. In the case of price increases, one would expect consumers to both reduce their expenditures and to substitute their expenditure towards goods with relatively lower price increases. This type of behavioural change in consumer behaviour is one of the prime aims of a carbon tax; goods with higher price increases will have created higher proportions of carbon dioxide.

Table 7 Demand Elasticities

	Beer	Wine	Spirit	Food	Fuel	Clothing	Trans	Service	Petrol	Tobacco	Other	Budget
Beer	-0.985	-0.166	-0.21	0.129	0.335	-0.248	0.133	-0.097	0.108	-0.092	0.095	0.851
Wine	-0.36	-1.124	0.08	-0.278	0.576	0.436	-0.14	0.123	-0.042	0.014	-0.286	1.59
Spirit	-0.399	0.069	-0.917	0.243	-0.035	-0.056	-0.044	0.097	-0.027	-0.025	0.092	0.941
Food	0.026	-0.025	0.023	-0.737	-0.019	0.006	0.057	-0.059	-0.055	-0.011	-0.116	0.435
Fuel	0.235	0.188	-0.011	-0.377	-0.483	-0.068	-0.043	-0.183	-0.173	-0.046	-0.039	0.252
Cloth	-0.107	0.089	-0.008	0.021	-0.039	-0.942	-0.016	-0.114	-0.141	-0.028	0.285	1.033
Trans	0.046	-0.022	-0.009	0.095	-0.023	-0.012	-0.956	-0.04	0.02	0.006	-0.105	1.746
Service	-0.034	0.016	0.021	-0.087	-0.079	-0.077	-0.035	-0.749	-0.003	-0.029	0.056	1.517
Petrol	0.1	-0.018	-0.016	-0.266	-0.239	-0.302	0.054	-0.009	-0.272	0.012	-0.045	1.441
Tobacco	-0.137	0.01	-0.017	-0.089	-0.106	-0.097	0.024	-0.155	0.019	-0.304	-0.149	0.301
Other	-0.058	-0.079	0.008	-0.284	0.05	0.332	-0.158	0.09	0.009	-0.06	-0.851	1.007

In order to measure the behavioural responses to increases in prices due to a carbon tax, it is necessary to have a consumer demand system, which includes values of own-price and cross-price elasticities. Unfortunately, due to the lack of micro data in Ireland, it has been impossible to develop such a comprehensive demand system. Madden (1993) calculated the most recent estimates for own-price and income elasticities for Ireland, using a number of different demand systems due to Deaton and Muellbauer (1980), Theil (1975) and Keller and Van Driel (1985). Baker et al.(1990), using their microsimulation model for indirect taxation (SPIT) applied to the UK Family Expenditure Survey (FES), have however estimated a demand system for the UK, producing estimates for own price, cross price and budget elasticities of household expenditures on 11 types of goods for the UK, outlined in table 7 below.

We shall assume that consumption behavioural responses to price changes would be quite similar in Britain and Ireland and so for this reason the elasticities produced by Baker et al. will be used for Ireland.

Table 8 Own price Elasticities in Ireland compared with the UK.

Good	Madden (1993) Minimum elasticity.	Maximum elasticity	SPIT model elasticity.
Food	-0.93	-0.50	-0.74
Alcohol	-0.87	0.28	
Beer			-0.99
Wine			-1.12
Spirits			-0.92
Tobacco	-0.68	-0.35	-0.30
Clothing & Footwear	-1.23	-0.52	-0.94
Fuel & Power	-0.47	0.09	-0.48
Petrol	-0.49	0.06	-0.27
Transport & Equipment	-1.20	-0.94	-0.96
Durables	-1.50	-0.78	
Other Goods	-0.73	-0.45	-0.85
Services	-1.38	-0.33	-0.75

As outlined in table 8, the SPIT model own price elasticities are quite similar to those developed by Madden (1993). Alcohol and other goods are the most dissimilar. There are a number of reasons why one would expect different estimates between the two studies. The demand systems used are different; the SPIT uses the Extended Almost Ideal demand system (EAI) due to Blundell, Pashardes and Weber (1989), which is not included amongst Madden's (1993) estimated demand systems[8].

In the UK it is known that smokers and car owners have different consumption elasticities to other consumers, however because of data limitations, we must make the simplifying assumption that all households have the same elasticities. The model also does not distinguish between fuel groups except in the case of the broad groupings, Petrol and Fuel. Therefore the model can only simulate the substitution between fuels to a limited degree.

As the price elasticities are only available for groupings of expenditure items, it is necessary to also take weighted averages of the percentage price changes. Applying the price elasticities to the percentage price changes gives us the percentage expenditure changes as a result of behavioural responses, which enables us to find the impact of the tax levied for each decile group.

[8] This model differs from those used by Madden in that it models the relationship between total expenditure and the budget share of each good using a polynomial in total expenditure of order two instead of order one. This is done because expenditure shares in total expenditure are non linear.

8. Policy Experiments

We now use the model developed in previous sections to carry out a number of policy experiments. Table 9 describes the 4 simulations considered. The analyses will be concerned with the impact of a carbon tax on income distribution, revenue and the reduction in carbon dioxide. The baseline reform is a tax placed only on household purchases of fuels. This is similar to the reform modelled by Scott (1992). The second simulation is the impact of a tax placed on the use of fuels at source in all sectors. This analysis therefore examines the direct and indirect impact on the income distribution of a carbon tax. The third simulation investigates the effect of placing the tax only on industrial inputs and not on domestic purchases of fuels by the household sector. The other simulation will be considered later and address the impact of a revenue neutral reform.

For the reasons outlined above, caution must be used when interpreting the results of the simulations. The ideal situation would be to have access to recent micro-data on household expenditures, an Irish specific demand system and recent input-output tables. Unfortunately this is not possible, so compromises have had to be made, resulting in large potential sources of error.

Table 9 Policy Simulations

Policy	Description
1	Direct Tax Only
2	Direct and Indirect Tax, no Transfers (Carbon Tax)
3	Indirect Tax only, No transfers
4	Direct and Indirect Tax, Transfer: Per person Basic Income

Experiment 1

The first experiment partially replicates the work done by Scott (1992), levying a tax only on fuels consumed by households. The indirect impact on households of fuels consumed by the electricity industry modelled by Scott (1992) is ignored. Using the assumptions about behavioural responses outlined in section 6, it was found that direct tax, without any transfer of tax revenues would cause a reduction carbon dioxide of 5.9%. The tax would raise revenue of £126m. Table 10 outlines the distributional effect of the tax.

Table 10 Tax as a percentage of Total Expenditure and Disposable Income

	1	2	3	4	5	6	7	8	9	10
Expenditure										
Direct Only	2.16	1.92	1.79	1.54	1.37	1.11	1.14	0.96	0.92	0.71
Disposable Income										
Direct Only	3.29	2.46	2.15	1.96	1.65	1.32	1.29	1.06	0.98	0.67

Experiment 2

Experiment two assumes an internationally levied carbon tax on all fuels which produce carbon dioxide. Casler and Rafiqui (1993) examined direct and indirect effects of a fuel tax in the USA and found it to have little distributional effects. This will produce both the direct effect found above and an indirect effect through the use of fuel used as an input for household purchases. Without any transfers, it was found that there would be a 7.6 % reduction in carbon dioxide, producing revenue of £181m and increasing total costs to households of £224m. As in the pre-behavioural response case, as described in table 11, the inclusion of the indirect effect of the tax shows that the tax is less regressive than if simply looking at the direct effect. Following from the differences between recorded expenditure and disposable income discussed in section 5, we see that the tax is more regressive when the carbon tax is measured as a proportion of disposable income rather than expenditure.

Table 11 Tax as a percentage of Total Expenditure and Disposable Income

	1	2	3	4	5	6	7	8	9	10
Expenditure										
Direct	2.11	1.88	1.75	1.51	1.34	1.08	1.12	0.94	0.90	0.70
Direct and Indirect	3.13	2.89	2.75	2.46	2.29	2.02	2.03	1.83	1.76	1.54
Disposable Income										
Direct and Indirect	4.79	3.70	3.31	3.13	2.77	2.41	2.29	2.02	1.88	1.46

In the next table we highlight the changes in expenditure as a result of a carbon tax. These changes are as a result of the demand system described in section 6 and the price changes described in table 5 above. The first column describes the impact on expenditures before tax of only placing a tax on fuels consumed by households, whereas the second refers to the impact on expenditures before tax of placing a tax on all fuels. The reduction in consumption of fuels and petroleum products is 25% and 31% greater respectively when indirect taxation is included. This emphasises the need to include the indirect impact of a carbon tax. When tax is included in the expenditure totals. It is found that although the amount of fuel consumed decreases the total amount spent on fuels actually increases. This is especially the case for household fuels due to the size of the carbon tax.

Table 12 Change in expenditure of goods as a result of an indirect carbon tax (%)

	Domestic Fuels only (not including tax)	All Fuels (not including tax)	All Fuels (including tax)
Beer	5.56	6.54	5.68
Wine	7.68	9.49	9.10
Spirit	-0.68	-0.94	-1.93
Food	-0.64	-0.54	-1.44
Fuel	5.39	6.16	-10.56
Clothing	-1.49	-1.63	-3.05
Transport	-0.20	-0.22	-1.59
Service	-1.15	-1.59	-1.92
Petrol	0.99	0.15	-7.12
Tobacco	-1.48	-1.92	-2.49
Other	0.79	0.95	0.29

Experiment 3

So far in this paper, we have seen that indirect taxes are less regressive than direct taxes. Casler and Rafiqui (1993) found similar results for the USA. In this experiment, we will examine the impact of levying a tax only on industrial inputs and not on fuels purchased through final demand. The size of the carbon tax needs to be increased in order to raise the same revenue as the tax used in experiment two. The indirect carbon tax would cause carbon dioxide to be reduced by 5.4%. Revenue would be £182m, with total costs rising to £317m. Total costs rise because of the impact of the increase in imported indirect taxes which are not revenue neutral[9]. Although total taxes increase, the impact distributionally is more equal. Carbon taxes as a proportion of expenditure in the bottom decile, would be just over 20% more than in the top decile, compared with over 100% in the case of experiment 2. When only national taxes are considered, this effect is even clearer; the bottom decile in this case pays 33% more taxes as a proportion of expenditure than the top decile compared with 140% more in experiment 2.

Table 13 Distributional impact of a carbon tax on industrial inputs only (As % of total Expenditure)

Decile	Total
1	3.3
2	3.2
3	3.2
4	3.0
5	3.0
6	2.9
7	2.9
8	2.8
9	2.7
10	2.6

Table 14 outlines the average percentage increase in the price of each expenditure group as a result of the carbon tax placed on industrial inputs only. Comparing with table 5, we see that as expected, the price increase is more equal across expenditure categories. The new average tax rate of non fuel categories triples in size whereas the tax rate on fuels almost halves. Both clothing and transport now ironically have higher price increases than petroleum products due to the higher fossil fuel (burning) inputs than the refining of petroleum products. The household fuel category still however has the highest tax rate, largely due to the impact of electricity generation. As a result of the demand system specified above, consumption[10] of domestic fuels would be reduced by the largest percentage. However consumption of petroleum products would decrease more than clothing or transport despite having a smaller percentage price increase. Even though the own price elasticity of petrol is lower than these two others sectors, the substitution effect of price changes in other product groups

[9] Total Carbon taxes in the import source country are revenue neutral, however if direct taxes are abolished from the household sector, taxes on industry will increase.

[10] Consumption is the defined here as expenditure less the carbon tax levied.

dominate. These cross price elasticities are stronger for petroleum products which results in a greater reduction in consumption.

Table 14 Change in price and consumption (not including tax) of goods as a result of an indirect carbon tax

	Increase in price	Change in Expenditure (including tax)	Change in Expenditure (not including tax)
Beer	3.09	2.91	-0.26
Wine	3.09	5.53	2.14
Spirit	3.09	-0.89	-3.86
Food	2.87	0.30	-2.49
Fuel	11.35	3.87	-6.71
Clothing	4.53	-0.53	-4.83
Transport	4.34	-0.18	-4.33
Service	0.89	-1.40	-2.24
Petrol	3.47	-2.22	-5.43
Tobacco	1.85	-1.40	-3.19
Other	2.15	0.47	-1.65

Experiment 4

A primary objective of a carbon tax strategy is to use the revenue generated by such a tax to reduce the distortionary impact of other taxes such as labour. As outlined in Callan, O'Donoghue and O'Neill (1994), introducing a basic income can help to reduce labour market problems resulting from tax/transfer system such as unemployment traps. In this experiment, we make the carbon tax reform nationally revenue neutral by redistributing some of the carbon tax revenues and introducing a small basic income payable to each person in the country.

Table 15 Income, expenditure and carbon tax per person per household gross income decile

Gross Income Decile	1	2	3	4	5	6	7	8	9	10
Expenditure per person	2686	2367	2202	2343	2611	2885	3216	3759	4249	5147
Disposable Income per person	1759	1849	1828	1839	2160	2420	2845	3405	3989	5435
Gross Income per person	1768	1866	1851	1928	2406	2858	3442	4272	5253	7530
Carbon Tax per person	84	68	61	58	60	58	65	69	75	79
Average Household size	1.36	2.12	2.93	3.65	3.74	3.98	4.11	4.12	4.33	4.72

We shall first introduce why a basic income would be a suitable means of redistributing carbon tax revenues so as to negate the distributional problems created by the tax. So far in this study, we have concentrated on households. In this experiment we concentrate on individuals. Although it is not possible to use an individual unit of analysis because of data constraints, we can look at the average carbon tax per individual in each gross income decile. Table 15 describes the average income, expenditures and carbon taxes per person per decile. This highlights the difference in the use of income measure; whereas average disposable income is largely monotonically increasing up the deciles, average expenditure does not. Average expenditure per person is higher in the bottom decile than in each of the next four deciles. This is as a result of the different sizes of households. Household size increases with gross income household decile. There is no relationship between gross income decile and carbon tax. The bottom decile and the top two deciles have the highest per person tax. The other deciles have relatively similar taxes.

Due to the relatively similar carbon tax per person in each decile, we now examine a redistribution of the tax revenue via a flat non-taxable basic income paid to each individual in the country. The tax revenue redistributed to the household sector includes all carbon taxes raised from this sector as well as half of the taxes raised from exports. The reason for redistributing export taxes is because we assume that any imported carbon tax is still charged in full. The value of the basic income is £67 per annum per person. It was found that there would be a reduction in Carbon Dioxide of 6.7% as a result of this reform. The reform is also almost distributionally neutral as the impact of the reform is on average less than 1% of expenditure.

Table 16 Net Change after Basic Income as percentage of Expenditure by Gross income decile.

Decile	1	2	3	4	5	6	7	8	9	10
Personal Basic Income										
Direct and Indirect tax	0.71	0.14	-0.21	-0.32	-0.20	-0.24	0.00	0.10	0.23	0.27
Indirect tax only	-0.11	-0.59	-0.91	-0.82	-0.44	-0.19	0.06	0.40	0.60	0.88
Reduction in VAT rates										
Indirect tax only	0.53	0.49	0.46	0.30	0.29	0.21	0.14	0.07	0.00	-0.09

Note. Redistribution includes all revenues directly and indirectly paid by the household sector as well as half that paid by the export sector. The latter is included to offset the impact of the tax on imported goods.

Table 17 Change in price and consumption (not including tax) of goods as a result of a revenue neutral carbon tax (percentages)

	Increase in price	Change in expenditure
Beer	0.98	7.61
Wine	0.98	12.69
Spirit	0.98	0.19
Food	0.91	-0.46
Fuel	18.70	-9.99
Clothing	1.44	-0.72
Transport	1.38	2.35
Service	0.28	1.50
Petrol	7.68	-3.87
Tobacco	0.59	-1.81
Other	0.68	2.56

As we saw in experiment 3, a carbon tax placed on industrial inputs would be distributionally neutral. The second row in table 16 investigates the distributive impact of combining this with a personal basic income of £92 per annum. This reform would be distributionally neutral, but more regressive than the revenue neutral direct and indirect tax. Carbon dioxide emissions would be reduced by 3.8%, which is much lower than that produced by the direct and indirect reform. The reason for the large difference in reduced carbon dioxide emissions is as a result of the larger redistribution necessary to maintain the revenue neutrality. As the indirect carbon tax is largely proportional to expenditure, another revenue neutral and distributionally neutral reform would be to reduce VAT rates. A VAT reduction equivalent to a reduction of about 3% would accomplish this. The impact on carbon dioxide reduction would be similar at 3.8%.

9. Conclusions

In this paper, we have analysed the impact of a carbon tax on the household income distribution in Ireland. Various international bodies such as the European Commission and the United Nations have proposed initiatives to reduce the size of emissions of greenhouse gasses of which carbon dioxide is one of the largest sources. One such initiative would be to introduce a tax on fuels proportional to quantity of carbon dioxide produced when they are bunt. In this paper, we examine the impact of such a tax on the household sector in Ireland.

This paper follows on from work done by Scott (1992) who largely looked at the direct impact of a carbon tax on fuels consumed by households. This paper expanded that analysis to include the impact of a tax on fuels used as inputs into goods and services consumed by households. The paper continues to use Scott's methodology of using representative individuals taken from published tabulations of the Irish Household Budget Survey. Access to micro data would however be much more effective in carrying out this analysis. As it is unlikely that a carbon tax would be introduced in isolation, this paper has incorporated the international sector into the model, assuming that all imports have the same carbon input structures as goods produced in the UK and described in Gay and Proops (1993). Carbon dioxide produced by inputs into domestically produced goods and services are described in O'Donoghue (1997).

One of the major criticisms of a carbon tax is that the distributional impact is quite regressive, with the burden of the tax falling proportionately more on poorer households. This is especially the case when a tax placed only on household fuels is considered (Smith, 1992; Scott, 1992). Other studies (Casler and Rafiqui, 1994; Symons et al, 1994) have shown that incorporating the indirect impact of the tax on inputs reduces this distributional effect however.

The main objective of a carbon tax is to reduce the emissions of carbon dioxide. In order for this to happen, individuals need to make some changes to their consumption behaviour. In order to analyse this, a demand system was used (Baker et al., 1990).

Four policy experiments were then carried out. The first partially replicated Scott's analysis focusing only on fuels directly consumed by households. The second modelled the impact of introducing a carbon tax on all fuel inputs. The tax would therefore have both a direct effect and an indirect effect on the goods they purchased. The third experiment looked at the impact of introducing a tax only on fuel inputs to goods and services which would only have an indirect effect on households. The final experiment looked at ways of redistributing the revenues of the carbon tax.

The primary conclusions are that introducing the indirect impact of the carbon tax produces different effects than simply analysing the direct tax on household fuel consumption. The direct and indirect tax is less regressive than the direct tax taken alone. More carbon dioxide is abated when considering both the direct and indirect impacts of the tax. Changes to expenditure patterns are also different. Levying a tax on fuel inputs to goods and services was found to be distributionally neutral, however it was less effective in reducing carbon dioxide emissions. In experiment 2, it was found that carbon dioxide emissions per capita and thus carbon taxes paid per capita were relatively constant across household income deciles. As a result a basic income transfer of resources was an effective form of redistribution in order to maintain the current income distribution. As the indirect tax was related more to expenditure per household, a reduction in expenditure taxes such as VAT would be a more suitable form of redistribution to maintain distributional neutrality.

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