Environmental RTDI Programme 2000–2006

The Macro-Economic Effects of Using Fiscal Instruments to Reduce Greenhouse Gas Emissions (2001-EEP/DS8-M1)

Final Report

Prepared for the Environmental Protection Agency

by

The Economic and Social Research Institute

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1 Introduction

The Kyoto agreement on restricting emissions of greenhouse gases (GHGs) has not attracted major attention in Ireland to date. This is partly because we are not used to debating policies which have such a long time horizon. The UN Framework Convention on Climate Change (UNFCCC) has been fully ratified and the clear objective of the UNFCC is stabilisation of atmospheric GHG concentrations at a level that would prevent dangerous anthropogenic interference with the climate system (Article 2), and that this will require significant cuts in GHG emissions. However, as the Kyoto Protocol has not yet been ratified, there remains some uncertainty as to 'how serious' the world is about tackling this issue. This uncertainty, which will remain for the foreseeable future, affects the commitment to policy changes in individual countries, making effective action difficult to achieve. However, the EU's commitment to emissions trading shows how seriously it is taking this issue. To be successful in reducing the world's emissions of greenhouse gases there will eventually have to be an inclusive agreement covering, not just the developed world, but also the bulk of the rest of world, most notably China and India. The prospect of such an agreement is today a long way off. There will always be a serious incentive for 'free riders' to opt out of such international agreements, hoping to gain a competitive advantage.

A key strand of the large volume of international literature on the economics of climate change has been consideration of what would be the most efficient economic way of tackling the problem at an international level. The OECD (Burniaux *et al.,* 1992) examined the international implications of agreements to reduce global carbon dioxide (CO_2) emissions. They considered the effects of a carbon tax and they showed how the costs of abatement of emissions of greenhouse gases as a share of national output would vary over regions of the world; they would be much lower for North America and Europe and significantly higher for the energy-exporting Less Developed Countries (LDCs).[1] Consequently, a provision for countries to trade emissions rights should be allowed for. They concluded that the costs of abatement for the industrial countries, acting on their own, would be virtually identical to what they would be under a global agreement, yet emissions would continue to grow. This highlights the importance of any international agreement including countries, such as China, if it is to be successful in the long run.

There is a strong commitment by the EU to making the agreement work, providing leadership to the rest of the world. If Russia ratifies the Kyoto protocol or if the US rejoins and ratifies the Protocol, it will become legally binding for all countries that have already signed it, including all existing EU members. In that event, the requirements of Kyoto (see Box 1) will assume additional importance for Ireland and other signatories. Even though there is some uncertainty about the commitment to this agreement outside the EU, the EU has made commitments that it will meet the objective set for itself of achieving an 8% reduction in emissions by the years 2008–2012 compared to a 1990 base level. Because of its relatively low level of development in 1990, it was agreed that for the 2008–2012 period Ireland's emissions could exceed their 1990 level by 13%. As Irish emissions have already exceeded this limit (by between 10 and 15 percentage points and this upper bound may be increased to 18 percentage points), there will have to be major policy changes over the next decade if Ireland's obligations are to be met. Similar problems clearly apply to many other EU countries, including Belgium (Government of Belgium, 2002), the Netherlands and Germany.

In 2000, the Irish government published its *National Climate Change Strategy* setting out a range of policy measures that were proposed to tackle Ireland's problem of excess emissions (Government of Ireland, 2000). While some of these policy measures have been implemented, their impact to date on the trend growth in emissions has been very limited. In his Budget speech (for 2003), the Minister for Finance indicated that the

1. However, the cost of abatement would be lower in absolute terms in a country such as China. Hence, at a global level, there would be an incentive for China to sell emission rights, making a bigger cut in emissions from coal, while offsetting the loss of output through revenue from permit sales.

Box 1.1

The Kyoto Protocol on Climate Change

The first international agreement on climate change, i.e. the UN Framework Convention on Climate Change (UNFCCC), was signed by over 160 countries at the 1992 Rio de Janeiro Earth Summit and entered into force in 1994. The objective of the UNFCC is stabilisation of atmospheric GHG concentrations at a level that would prevent dangerous anthropogenic interference with the climate system. At the third Conference of Parties (COP-3) of the UNFCC meeting in Kyoto in Japan in December 1997, the Parties agreed further binding targets for GHG emissions reductions in the Kyoto Protocol to the Convention. The result was the adoption of a legally binding international agreement for climate protection – the Kyoto Protocol. The Kyoto Protocol represents the culmination of years of negotiations to fortify the 1992 Rio de Janeiro climate change agreement.

The main points of the Protocol are as follows:

- Article 3 sets out the Targets and Timetables. It provides that 39 of the most developed countries should reduce GHG emissions by an aggregate 5.2% from 1990 levels between the period 2008 and 2012. Each nation has a different target, ranging from an 8% reduction (the EU) to a 10% increase (Iceland). Table A1 details the requirements for some of the world's largest economies. Each party must show verifiable progress towards meeting its target by 2005.
- The gases covered by the Protocol are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6). These six gases are treated as a 'basket'. This allows a degree of flexibility in reaching the target, as reductions in one gas can be substituted for reductions in others.
- Article 4 allows Parties to join together in order to meet their targets. This provision satisfied the demand from the EU that it should be permitted to comply as a group or multi-country 'bubble'. In this case, the burden of its required 8% reduction is shared between countries based on forecast growth rates, with converging countries permitted some increase in emissions (see Table A1).
- The Protocol allows for Carbon Sinks, i.e. land and forestry practices that remove carbon emissions from the atmosphere. They represent a low-cost option to governments, but are defined ambiguously in the Protocol and will prove difficult to measure.

The Protocol also introduced three 'flexible mechanisms' that are intended to facilitate cost-effective implementation:

1. Emissions Trading (Article 16). Polluting entities in individual countries are allocated permits for their emissions of greenhouse gases consistent with the government's target, and these can be traded on the international market.
2. Joint Implementation (Article 6). This is where one nation gets credit for implementing a project to reduce emissions or enhance sinks in another country.
3. Clean Development Mechanism (Article 12). Similar to Joint Implementation but with additional safeguards and provisions, this allows developed countries to gain reduction credits for investments in appropriate projects in developing countries.

There are many issues still to be resolved. No agreement was reached on the participation of developing countries, yet it is predicted that they will produce the largest share of carbon emissions by the middle of the century (especially China and India). Furthermore, the Protocol has left specifics on emission trading, the clean development mechanism, carbon sinks and compliance and enforcement to be defined at a future date.

Table A1. Quantified emission limitation or reduction commitment (percentage of base year).

Party	%	Party	%
Australia	108	**Ireland**	113
Canada	94	**Germany**	79
USA	93	**France**	100
Japan	94	**Greece**	125
Russian Federation	100	**Spain**	115
		UK	88.5
		Total EU	92

Irish government is proposing to introduce a carbon tax from the end of 2004 to help Ireland to meet its Kyoto obligations.

In addition, the EU are introducing a scheme of tradable emissions permits applying to electricity and certain key energy-using sectors in industry. This scheme will provide a significant incentive for these sectors to reduce their emissions. As part of the scheme, the EU has decided that permits covering part of their emissions would be given free to existing firms (this is referred to as ‘grandparenting’ the permits).

The first empirical work assessing the macro-economic implications for Ireland of a carbon tax was completed in 1992 (Fitz Gerald and McCoy, 1992) and it examined the effects on the Irish economy of imposing a carbon tax along the lines then proposed by the EC Commission. They showed that a tax, roughly equivalent to €30 per tonne of CO_2 in today’s prices, would have increased tax revenue by just under 2% of GNP. The eventual impact of the tax on the economy would have depended on how the revenue from the tax was spent.

Fitz Gerald and McCoy considered alternative methods of recycling the revenue collected from the tax, namely repaying the national debt and reducing social-welfare contributions. If the tax revenue were used to fund a reduction in social-welfare contributions then the net impact on the Irish economy could be positive, resulting in GNP being up to half a percentage point above what it otherwise would have been. This would have also impacted on employment and they estimated an increase in employment of approximately 0.75% after 10 years. Their results indicated that the imposition of such a tax in the 1990s would have served both to reduce GHG emissions and to stimulate growth and employment in Ireland.

In a 1997 study, Conniffe *et al*. (1997) considered the cost of abatement through different policy options. The study estimated the cost of reducing emissions through changes in technology, especially in the electricity sector. It suggested that by switching to gas-fired generation a significant reduction in emissions could be achieved relatively painlessly. However, within the electricity sector, abatement costs would rise rapidly once the possibilities of this switch were exhausted.

Later work in Ireland has focussed on the impact of carbon taxes (or tradable emissions permits) on the competitiveness of Irish industry. The study commissioned by IBEC (Boyle, 2000) identified competitively vulnerable sectors, which have energy cost to output ratios in excess of 2%. That study examined the implications for competitiveness of a range of tax options. It was argued that, even with tax revenues being fully recycled to industry in the form of a wage and salary subsidy, these competitively vulnerable sectors would still suffer significant net losses. In addition, the overall impact on GHG emissions would be insignificant. The study by Indecon (2002) recommended that non-taxation measures should be used to bring about the reduction of emissions in the enterprise sector, though they also saw some limited role for taxation.

An important recurring issue in the literature is that the various methods of recycling the revenue raised by a carbon tax can result in very different costs and economic effects for the combined policy action. Goulder *et al*. (1999) argue that in a ‘first best’ situation the effects of different methods of recycling the revenue would be identical at all levels of emissions. However, they show that pre-existing taxes on labour and capital serve to drive a wedge between the outcomes under alternative methods. As a result, they show that in the real (‘second best’) world where non-environmental taxes are substantial, policies that do not recycle revenue through reducing taxes (e.g. ‘grandparenting’ tradable permits) cost some 50% more than those that do.

A report by the Congressional Budget Office in the USA (2000) on the distributional effects of alternative policy designs to reduce CO_2 emissions also found that the ultimate effects on the economy of a carbon-allowance programme depended on the method of revenue recycling. They considered the effects of reducing corporate taxes or of providing each household with an identical lump-sum rebate as means of reducing the costs that a cut in emissions would have on the economy. They found that decreasing corporate taxes would lead to gains in economic efficiency. However, the recycling of revenue to households through lump-sum rebates failed to encourage additional work effort, saving or investment by households.

A study (Mulder, 2002) on the effects of emissions trading in the Netherlands found that the loss in net national income, as a result of the introduction of emissions trading, is lowest when the additional revenue is used to reduce tariffs on labour and capital and highest when there is a lump-sum transfer to households. This is replicated in a recent Belgian study (Bossier *et al*., 2002).

In their 2001 study, Fitz Gerald *et al*. (2001a) evaluated the potential role of tradable emissions permits as a mechanism for achieving the required reduction in emissions in Ireland. They found that a purely Irish scheme would not be practical but that an EU-wide scheme could work effectively to deliver the required reduction at least cost. As with all such permit schemes, it would be very important that the permits were auctioned if the economic costs to the Irish economy were to be minimised. If such a policy were adopted, its impact would be similar to that of a carbon tax levied at the same rate as the potential price of the permits.

As a result of this analysis, a major concern for policy makers will be to ensure that the burden of a carbon tax is minimised, and that it is equitably distributed through the redistribution of the revenues collected. In the case of companies, it is likely that certain very heavy energy users will need special treatment to ensure that they do not suffer an unfair competitive disadvantage on international markets. It is also the case that those on low incomes will need special consideration because they spend an above-average share of their income on energy. As a result, they are more exposed than richer households to the effects of policy measures aimed at reducing carbon emissions.

The proposal examined in this report is for a tax applied on the carbon content of all forms of energy consumed in Ireland. Thus coal, which generates a higher quantity of carbon dioxide when it is burnt than oil or gas, would be subject to a higher rate of tax than gas or oil. The higher tax on carbon-rich fuels would provide an incentive, firstly to economise on energy, and secondly to switch to fuels which generate lower quantities of carbon dioxide. In principle, the effects of tradable emissions permits would be the same as the effects of a tax of the same amount. As a result, the analysis in this report applies to both types of policy instrument.

In this report, we describe in Section 2 the set of models used in this analysis: a new electricity and a new energy sub-model, both of which are integrated into the HERMES macro-economic model of the Irish economy. Section 3 uses the model to generate a baseline forecast for energy demand and emissions of carbon dioxide out to 2020. Using this model, Section 4 estimates the direct impact of a carbon tax on energy demand and emissions. Section 5 analyses the macro-economic impact of the tax under different assumptions concerning how the revenue is used. Finally, Section 6 presents conclusions.

2 Methodology

The quantification of the macro-economic effects for Ireland of a carbon tax or tradable emissions permits can only be undertaken within the framework of a macro-economic model. We use the ESRI's Medium-Term Model (HERMES), which was initially developed in the 1980s as part of an EC-wide set of models, to deal with energy policy issues. A new energy sub-model is embedded within the HERMES model of the Irish economy (Fitz Gerald *et al*., 2002). The HERMES model has already been used to produce macro-economic forecasts for Ireland as far as 2020. It can now produce consistent forecasts of energy demand and of GHG emissions from energy using the new energy sub-model. The modelling framework makes it possible to simulate the effects of alternative policies on reducing GHG emissions.

2.1 Description of the Energy Model

The energy model is built up as four separate, though interrelated, blocks.[2] The model examines the demand for six types of primary energy (coal, oil, peat, gas, electricity and renewables) by six sectors of the economy (industry, households, services (commercial and public), agriculture, transport and energy). The demand for energy in the various sectors is modelled in the first block of the model. In each sector, electricity demand is modelled separately from the 'rest of energy' and then the 'rest of energy' category is broken down between the different fuels. The electricity demand from all sectors is then aggregated to give total electricity demand.

Given the demand for energy, the second block then covers the electricity generation sector, based on a series of exogenous engineering relationships. A separate electricity model examines how these engineering relationships determine the optimal fuel mix in the sector. The results of this electricity model are used as an input into the wider energy model.

The third block of the energy model generates the CO_2 emissions associated with the levels of energy consumption. Since each fuel will release a different amount of CO_2 when burned, the aggregate emissions from energy are obtained by multiplying the estimate of consumption of each fuel by an appropriate emissions factor.

Finally, the fourth block of the energy model develops a series of relationships that provide a direct link between the energy model and the rest of the HERMES model. Price determination for different fuels is included within this block. The price determination takes account of the possible impact of a carbon tax (or of tradable emissions permits). Given the mix of fuels used in each sector, and allowing for the distribution margin, the price of energy used by each sector is derived.

2.2 Description of the Electricity Sub-Model

We have developed a simple model of the electricity sector that takes account of the economics of different types of generators (using different fuels) and of the varying loading of the system over the course of the average day (Fitz Gerald, 2002). In addition to modelling the costs of generating electricity from different fuels, we also model the impact of carbon taxes (or a regime of tradable emissions permits) on the prices of the different fuels used by the electricity system.

The model estimates the short-run and long-run marginal cost of producing electricity from each fuel using different technologies. Because the demand for electricity varies considerably over the day, and over the course of the year, some electricity plant will be used with a very high load factor – base load. Some plant will only be used during waking hours – mid-load – and some plant will be used for a very limited amount of time to cover temporary peaks. Because plant used only to cover peaks experiences very low load factors, the recovery of capital costs and other fixed costs has to be made over a small volume of electricity. This means that the long-run marginal cost of production varies greatly depending on the utilisation of the plant.

2. A complete description of the model is available in ESRI Working Paper 146.

The model assumes that plant is used optimally to meet the three types of load. Plant with a low capital cost per unit, or older plant that is fully depreciated, tends to be used to cover peaks, whereas very different technologies may be appropriate to meet base-load requirements. The optimal utilisation of plant is considered as a function of the fuel price and the model estimates how changes in carbon taxes would affect the choice of plant.

Table 2.1 shows an example of how the long-run marginal cost of plant is affected by changes in the rate of carbon tax (price of tradable emissions permits). Existing plant is assumed to be fully depreciated whereas new plant is assumed to have to cover its full costs. The results of this model are fed into the broader energy model as an exogenous input.

2.3 Energy Demand

Energy demand in each sector is driven by an appropriate measure of economic activity in the sector and it is moderated by changes in relative energy prices. Figure 2.1 plots energy demand from 1970 to 2002 and GNP

Table 2.1. Estimated cost per kWh (€) for base-load plant 2001 for 0% and 20% tax rates.

Technology	0%	20%
Coal – existing plant	0.0263	0.0425
Coal plus flue-gas desulphurisation (FGD)	0.0298	0.0465
Oil – existing plant	0.0525	0.0674
Gas – existing plant	0.0537	0.0638
Gas – new combined cycle gas turbine (CCGT)	0.0424	0.0494
Gas – new open cycle gas turbine (OCGT)	0.0633	0.0745
Peat – existing	0.0837	0.1163
Peat – new	0.0493	0.0718
Hydro	0.0281	0.0281
Wind – new	0.0415	0.0415
Wind & gas – new OCGT	0.0524	0.0580

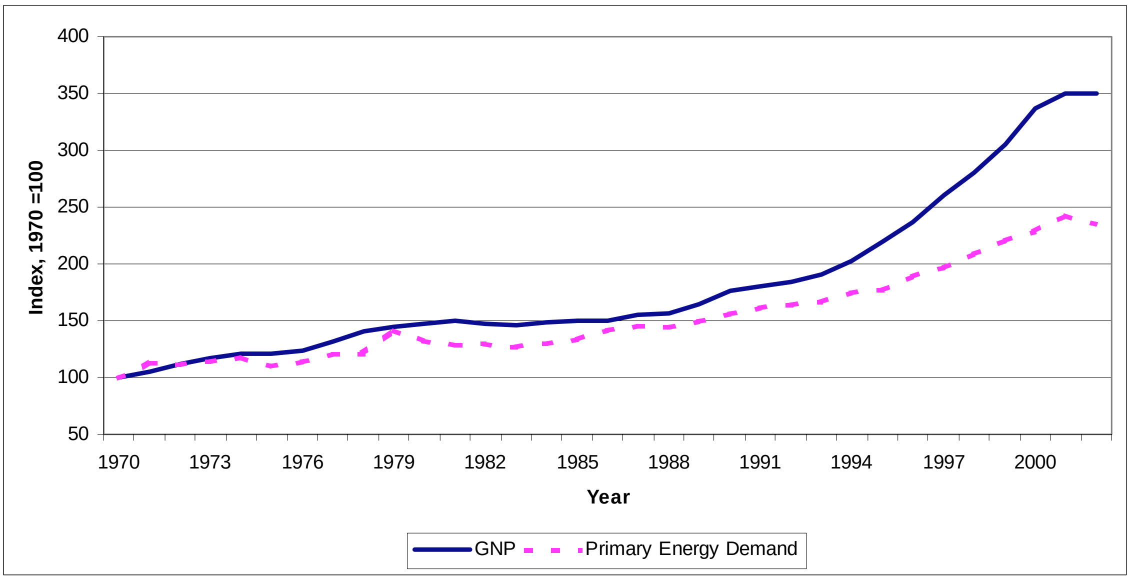

Figure 2.1. Energy Demand and GNP.

measured in constant prices.[3] Excluding the periods of the oil price hikes of 1973–1974 and 1979–1980, one can see that energy demand rises as GNP rises and that there is little or no growth when GNP is static (as in the early and mid-1980s). From the graph, it is also clear that energy demand has been rising at a slower rate than GNP since the early 1990s. The factors that explain this pattern include the fact that Irish industrial growth in recent years has taken place in less energy-intensive sectors, the oil price hikes in the 1970s triggered the development of more energy-efficient equipment and practices, and in the household sector, as consumption reaches saturation, the rate of growth begins to slow. It may also be explained by the rapid decline in use of solid fuels (coal and peat) as consumers switch towards fuels with higher end-use efficiencies, such as gas.

Separate energy demand equations are estimated for each sector. The basic approach used is that energy demand in each sector is modelled as a simple function of income, or another appropriate activity variable, and relative prices. From the estimated relationships, we calculate elasticities measuring how responsive energy demand is to economic growth or the energy intensity of growth. The elasticity of energy demand with respect to GNP is defined as the percentage increase in energy demand, given a 1% increase in GNP. An elasticity of unity would imply that GNP growth of 1% leads to a 1% increase in energy demand, while an elasticity of less than unity would imply a decoupling from growth. The energy elasticity with respect to relative prices is important when considering the impact of carbon taxes or tradable emissions permits. It measures how responsive overall energy demand (or demand for different fuels) is to changes in prices induced by the tax.

By choosing an appropriate functional form we can estimate energy elasticities that rise or fall over time to best fit the information in the data sample. Most of the specifications in the model allow the demand elasticity to fall over time; this is consistent with the findings in many other studies on household demand[4] and with the trend towards the use of more energy-efficient technologies and fuels. Our choice of model specification allows for the fact that demand is slow to respond to changes in income or prices. Very often these changes require capital investment (e.g. in new boilers) that takes time to implement.

Our estimates suggest that demand elasticities for energy in Ireland have fallen over time. However, in some cases, there is doubt as to whether they will continue to fall at the same rate in the future, so that, in forecasting, allowance must be made for the possibility that elasticities may stabilise at current estimates as technical advances peter out and the process of inter-fuel substitution is completed. This is an important consideration in using the model for forecasting purposes.

The absence of consistent price data spanning the period of major oil-price shocks in the 1970s has, in the past, proved a major obstacle to modelling the sensitivity of energy demand to price shocks. However, a separate study (Fitz Gerald *et al.*, 2001b) has put together a set of price data that go back to the 1960s, allowing more sophisticated analysis of the forces driving energy demand. As with any such exercise carried out long after the event, these price data, while more satisfactory than those previously available, are still not fully reliable.

Using these price data, we can test whether the oil price shocks of the 1970s imparted a significant permanent effect to energy demand through stimulating extensive research and development into more energy-efficient technologies. Our tests indicate that this ratchet effect from large price shocks that were believed to be permanent, subsequently led to a permanent decline in the consumption of energy for any given level of demand and prices in the industrial sector. While the energy sub-model does not explain how the fuel mix is likely to change in response to major changes in relative prices of energy, it performs reasonably well in explaining the sensitivity to overall changes in the real price of energy.

Tables 2.2 and 2.3 set out the main results for the household, services and industrial sectors. The long-run

3. The common unit used to aggregate and compare different fuels is the TOE (Tonne of Oil Equivalent – the amount of fuel needed to produce the same amount of energy as a tonne of oil) with the ‘price’ of aggregate energy also measured per TOE.

4. These studies suggest that, for households, energy is a necessity with a low-income elasticity of demand (Conniffe, 2000a,b). See also Duffy *et al.* (1999), p. 75.

Table 2.2. Results – non-electricity energy.

	Long-run price elasticity	Long-run income elasticity	Long-run 'maximum price' elasticity	Standard error of equation
Household	–0.24	0.46		5.9
Services	–0.36	0.59		15.9
Industry		0.71	–0.35	5.6

Table 2.3. Results – electricity.

	Long-run price elasticity	Long-run income elasticity	Standard error of equation
Household	–0.24	1.09	2.6
Services	–0.29	0.70	2.8
Industry	–0.31	0.23	3.4

elasticity of demand for non-electricity energy in the household sector is around –0.2, i.e. a 1% rise in the price of non-electricity energy will, after a number of years, lead to a 0.2% fall in energy demand. This indicates limited sensitivity to price changes. It is of a similar order of magnitude to the estimated price elasticity for electricity. The long-run income elasticity for non-electricity energy is low, indicating that the demand for energy rises more slowly than income, as would be expected (consumption of energy is moving towards saturation levels for certain products such as central heating, together with product change towards more energy-saving devices). Nevertheless, the positive elasticity ensures that rising affluence increases the demand for energy by the household sector. The estimated equation for household demand for non-electricity energy is not as well specified as the equation for electricity.

The data for energy use in the services sector of the economy are essentially residually determined, so all the errors in the data are likely to be concentrated here. In addition, this sector is very heterogeneous in character. Consequently, it is more difficult to model energy consumption behaviour in this sector than in the other sectors of the economy. This helps explain the high standard error of the equation that models the demand for non-electricity energy in the sector. Nonetheless, the estimated elasticities for non-electricity energy are plausible and in the same range estimated for electricity and for the household sector.

In estimating industrial energy demand, there is evidence of a ratchet effect from prices or an irreversible efficiency improvement effect (Conniffe, 1993). The long-run elasticity on this maximum price variable indicates that sharp energy price hikes, that were perceived to be permanent, triggered the introduction of energy-saving technologies. These large price rises triggered major research worldwide resulting in major improvements in efficiency. However, if price increases only occurred in Ireland, in the future the resulting volume of research would be unlikely to make anything like the same impact. This must be taken into account in using the model to examine the effects of future price changes.

Table 2.4 shows the root mean squared percentage error (RMSPE) for some of the key behavioural variables in the energy model when it was simulated within sample. This is a measure of how reliable the model was when applied to historical data and gives an indication of its reliability when used out of sample. The RMSPE for overall energy demand at 2.9% is reasonable, although the errors for individual sectors are higher, particularly for the services sector. Thus, in the past, the errors for individual sectors tended to cancel one another out. The RMSPE for total CO_2 emissions and electricity are also within acceptable limits.

Table 2.4. Within sample performance.

	RMSPE
Total final demand all energy	2.9%
Electricity	4.7%
Carbon dioxide	2.4%

2.4 Description of Links with the HERMES Macro-Economic Model

The activity variables driving energy demand, and hence carbon emissions, are derived from the forecasts produced with the help of the HERMES model (Bergin *et al.*, 2003). These are inputs into the energy sub-model.

The price of energy inputs into each sector for each fuel is modelled as a function of the import price of the different fuels, of carbon (and energy) taxes and of the distribution margin. For example, because of the cost of delivery to households, the cost of the raw fuel accounts for a minority of the cost of the energy sold to that sector. The weighted average energy price for the different sectors then affects the competitiveness of the tradable (manufacturing) sector in the macro-economic model as well as consumer prices. The tax revenue from any carbon tax is then fed back into the government sector in the HERMES model. The HERMES model itself is documented in Bradley and Fitz Gerald (1991) and Bradley *et al.* (1993). A non-technical description of the model is available in Bergin *et al.* (2003).

3 Forecasts of Energy Demand and Emissions

Before any assessment can be made of the effects of meeting a particular emissions target, CO_2 emissions are forecast using the HERMES model assuming a tax of €20 per tonne of carbon dioxide. This model concentrates on modelling carbon dioxide emitted from energy use. A forecast of energy demand is needed before any estimate of emissions can be made. The methodology for forecasting energy demand to the year 2020 relies on the comprehensive forecasts given in the ESRI's Medium Term Review: 2003–2010 (Bergin *et al.*, 2003). Forecasts for the key macro-economic variables are combined with the estimated elasticities, described in the previous section, to produce our energy forecasts. The baseline for this study was then obtained by setting the carbon tax to zero.

3.1 Macro-Economic Assumptions

As outlined in Bergin *et al.* (2003), the Irish economy over the coming decade, while growing more slowly than in the 1990s, is still expected to grow more rapidly than those of its EU neighbours. However, as the special demographic circumstances that underpin this outlook revert to a more normal European pattern, the rate of growth can be expected to gradually slow.

The macro-economic assumptions underlying the energy demand forecast to the end of the decade and beyond are based on the benchmark forecast in Bergin *et al.* (2003). This benchmark forecast is then applied to the energy sub-model to derive the demand for energy (and GHG emissions).

The key macro-economic assumptions for the period to 2020 are shown in Table 3.1. Here we show the key variables that are used in the energy sub-model to generate forecasts of energy demand. The forecasts for the number of households under each scenario are derived from the ESRI's demographic sub-model and they are consistent with the other macro-economic aggregates shown in the table.

In preparing the forecasts of energy demand, we have assumed that the price of the different fuels rises in line with the forecast rise in oil prices. In addition, in the electricity sector, we have assumed that the Moneypoint coal-fired generating station continues in operation throughout the forecast period. However, the oil stations may well drop out of the system by 2010 with the introduction of emissions trading. In spite of new, more efficient, peat stations being built, it will probably be economic to close all peat stations by 2010 in the face of a price of carbon dioxide of €20 per tonne. The higher cost of using fossil fuel powered generating plant will make a much wider deployment of renewable energy economic. Provided that the planning obstacles to such a deployment are dealt with, and that the electricity system can absorb this amount of wind energy, renewables could account for at least 15% of production by 2020. An allowance is made for increased efficiency of new gas stations. This increased efficiency will also reduce the use of electricity in the energy transformation sector. The effects of the closure of IFI have been included.

Table 3.1. Macro-economic assumptions, annual average growth rate, % p.a.

	2000–2005	2005–2010	2010–2015	2015–2020
GNP	3.1	5.4	3.5	2.8
Consumption (constant 1995 prices)	3.0	3.9	3.5	2.7
Gross output, traditional manufacturing	1.9	2.4	0.3	0.6
Real personal disposable income	3.5	3.7	3.2	2.5
Households	2.3	7.6	3.8	1.9
Population over 15	1.4	1.1	1.0	1.0

	2005	2010	2015	2020
Persons per household	2.8	2.7	2.5	2.5

Obviously, without a carbon tax or emissions trading these changes would not take place.

3.2 Energy Demand Forecast

On the basis of our forecast for GNP, we have estimated primary energy demand and total final consumption of energy by sector. The forecasts for 2010 are shown in Table 3.2. The table compares the results from the new energy model with the results from the old model used in Duffy *et al*. (2001), with the revised macro-economic forecasts and the revised energy demand data applied to the old model. Over the 20-year period from 1990 to 2010, we are forecasting an annual average GNP growth of 5.5%. Demand for primary energy is forecast to rise at an annual average rate of 2.7% over the same period.

We can see from Fig. 3.1 that the new model produces a slightly higher forecast for primary energy demand for the period 2000–2010 than the old model. Using the forecast from the new model, primary energy demand in 2010 would be around 16.7% higher than in 2000 (Table 3.2). The new model estimates that, by 2010, the total final consumption of energy will be around 24% above its 2000 level on the basis of a tax of €20 per tonne of CO_2.

Table 3.2. Energy demand and final consumption of energy, 2010 compared to 2000, % change.

	Old model	New model
Demand for primary energy	15.7	16.7
Final consumption of energy		
Total	28.5	24.3
Households	20.1	20.8
Industry	11.4	14.9
Services	39.3	32.9
Transport	42.8	31.6

There is some divergence between the forecasts produced by the different models at a sectoral level but at an aggregate level both models produce similar results. The results from the new model suggest that final consumption by households in 2010 will be 21.8% above its 2000 level (Fig. 3.2), which is similar to the forecast produced by the old model. The estimate for the industrial sector shows lower energy consumption in the near term and higher energy consumption from around 2008 on, compared to the previous results. It is estimated that final consumption of energy in the industrial sector will be 14.9% above its 2000 level in 2010 (Fig. 3.3).

We have also estimated the final demand for each fuel and the results are set out in Table 3.3. The new model estimates higher consumption of coal, gas and electricity and lower consumption of peat and oil, when compared with the results of the previous model. Demand for oil will increase by around 23% of its 2000 level, and final consumption in 2010 will exceed 8.2 million TOE. The demand for gas is forecast to experience the strongest growth of all the fuels, with final consumption in 2010 at

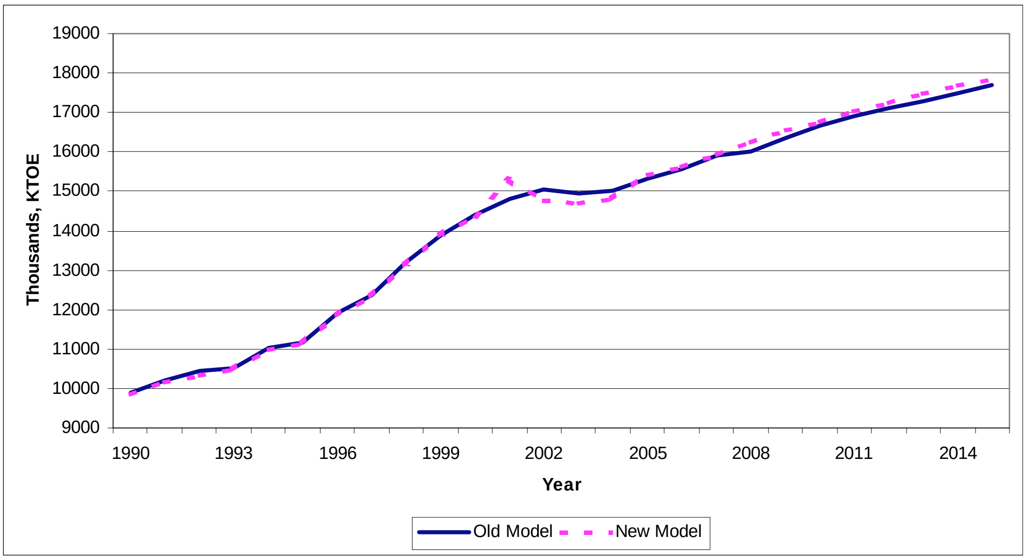

Figure 3.1. Primary energy demand.

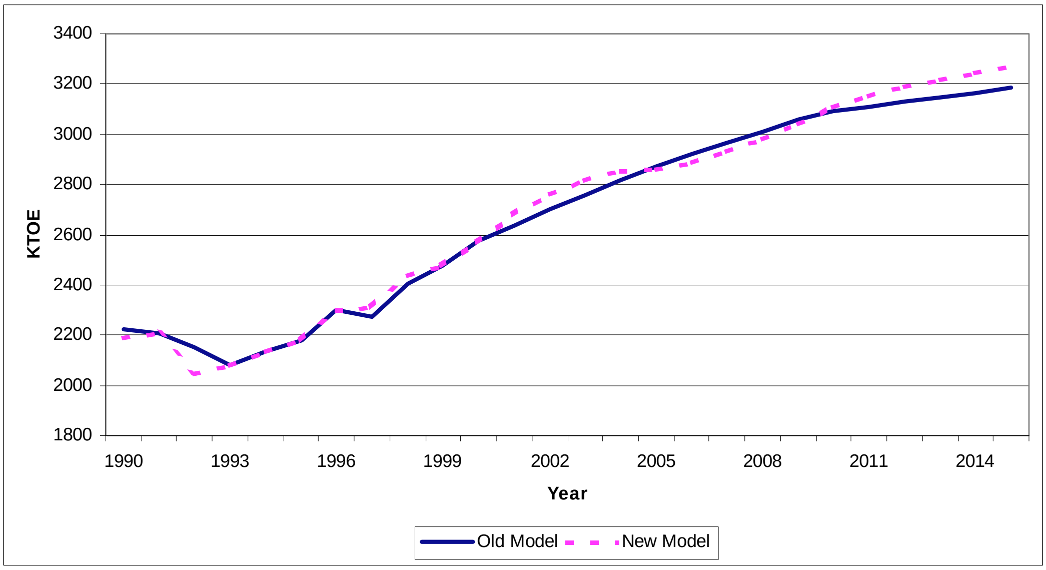

Figure 3.2.Total final energy consumption by households.

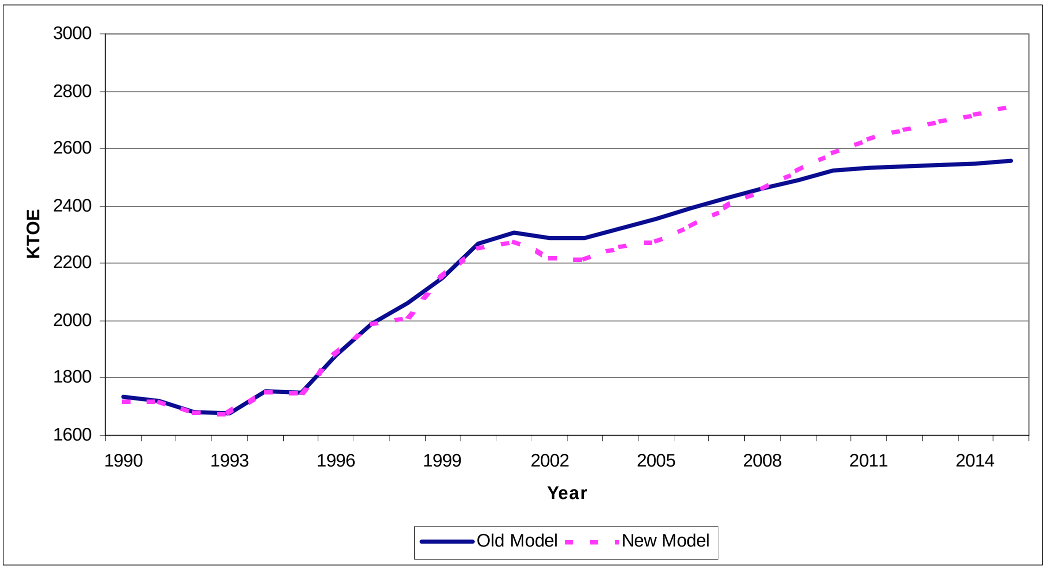

Figure 3.3. Total final energy consumption by industry.

67% above its 2000 level. Electricity demand is forecast to increase by around 41% of its 2000 level and final consumption is likely to exceed 2.4 million TOE in 2010. The decline in the consumption of coal and peat is likely to continue over the forecast horizon, with final consumption of both fuels falling by 56% and 59%, respectively, of their 2000 levels by 2010.

3.3 Forecast Carbon-Dioxide Emissions

The forecasts described above for energy demand have significant implications for the environment. The burning of fossil fuels releases carbon dioxide, which is the largest contributor to GHG emissions into the environment. In forecasting CO_2 emissions, consumption of each fuel must be multiplied by an appropriate emissions factor, since each type of fuel will release a different amount of carbon dioxide when burned. In addition, an adjustment has to be made to the emissions from electricity as they depend on the fuel mix and the efficiency of generation. By breaking down the final consumption of electricity into a primary energy requirement for coal, oil, peat and gas, with each fuel

Table 3.3. Final consumption of energy, by fuel, 2010 compared to 2000, % change.

	Old model	New model
Coal	–69.8	–55.5
Oil	31.4	22.6
Gas, excluding feedstock	64.5	67.0
Peat	–23.6	–58.6
Electricity	37.5	41.2

requirement including primary energy use for electricity generation, we can calculate the CO_2 emissions for electricity.

From Table 3.4, we can see that coal and peat have the highest emissions factors as they are 'dirtier' fuels and they have a higher share of emissions than of total final consumption. Gas has the lowest emission factor;[5] it is less then half the emission factor of peat, while oil lies somewhere in between. Emissions from electricity tend to be disproportionately high, as much of the energy of the individual fuels is lost in generation. Total emissions of carbon dioxide are likely to grow at a rapid rate over the forecast horizon. Total emissions stood at just over 31 million tonnes in 1990 and, even with a tax of €20 per tonne of CO_2, they are likely to be 47 million tonnes in 2010, 47.4% above the Kyoto base year[6].

Table 3.5 shows the CO_2 emissions by sector for 1990, 2000 and 2010 and Fig. 3.4 shows the percentage contribution to CO_2 emissions by sector for the same years. In the table, the CO_2 emissions from power generation have been allocated to the various sectors in proportion to their electricity use. By 2010, emissions in the transport industry are forecast to increase by over 153% of its 1990 level, resulting in the sector accounting for approximately 34% of total emissions by 2010. Emissions from the household sector are likely to remain relatively stable over the forecast period. Emissions from the industrial and services sectors are forecast to increase by 29% and 69%, respectively, on their 1990 levels. Emissions from the agricultural sector are forecast to decline over the period, with emissions from the sector accounting for less than 2% of total emissions by 2010.

5. This ignores renewable energy sources, which do not emit carbon dioxide.

6. The total emissions here include emissions from kerosene used by aircraft, but emissions from international flights are excluded from the Kyoto limits.

Table 3.4. Forecast CO_2 emissions from energy, by fuel ($\times 10^3$ tonnes).

	Emission factor (tonne/TOE)	1990	1995	2000	2005	2010	2015
Coal	3.59	8565	7595	7878	7267	6979	6735
Oil	3.05	13109	16726	24170	23189	25545	26292
Gas	2.30	3326	4406	7036	11196	13732	15933
Peat	4.83	5749	5155	3435	3512	520	262
Feedstock		990	973	883	0	0	0
Total emissions		31739	34855	43402	45163	46775	49222
Change on 1990, %		0.0	9.8	36.7	42.3	47.4	55.1
Electricity	8.93	10828	13185	15542	16290	15005	15913

Table 3.5. Forecast CO_2 emissions by sector ($\times 10^3$ tonnes).

	1990	2000	% increase on 1990	2010	% increase on 1990
Households	10426	11198	7.4	11098	6.4
Industry	7956	10353	30.1	10240	28.7
Services	4825	7358	52.5	8136	68.6
Agriculture	1044	1300	24.4	1058	1.3
Transport	6194	11941	92.8	15699	153.4

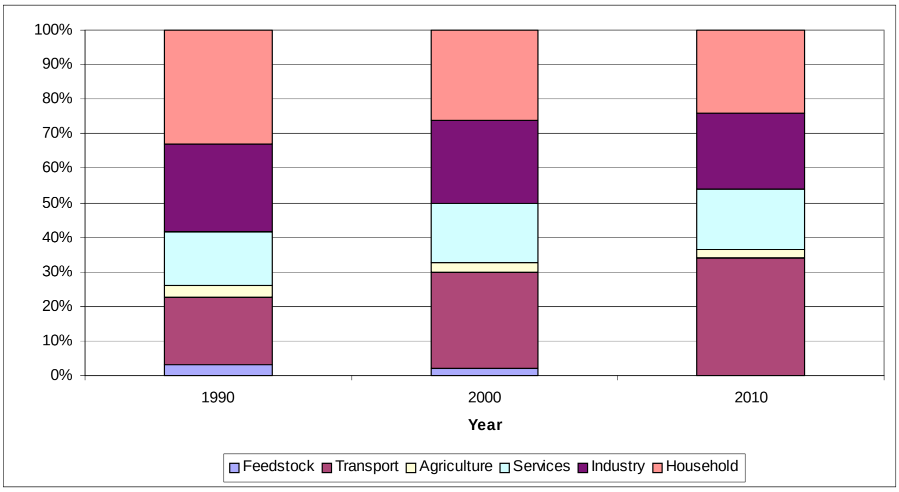

Figure 3.4. Source of CO_2 emissions by sector.

Table 3.6. Forecast GHG emissions ($\times 10^3$ tonnes).

	1990	1995	2000	2005	2010	2015
CO_2 – Energy	29775	32620	41406	43819	45376	47753
CO_2 – Industrial processes	1931	2041	2645	2368	2672	2707
CO_2 – Solvents	92	98	109	112	112	112
Methane	11900	12595	12785	10208	8919	8919
N_2O	9544	10050	10760	10657	9327	9370
Other	0	179	547	0	0	0
Total	53241	57583	68252	67165	66405	68860
Percentage change on 1990	0.0	8.2	28.2	26.2	24.7	29.3

Carbon dioxide is only one of a number of greenhouse gases. In the case of Ireland, in addition to emissions from energy use, there are also significant emissions of carbon dioxide from industrial processes and emissions of CH_4 and of N_2O are also important contributors to Ireland's total emissions. The emissions of the latter two gases come primarily from agriculture.

In Table 3.6, we show a composite forecast for emissions of greenhouse gases out to 2010.[7] The emissions of carbon dioxide from energy use are explained above. The forecasts are derived from earlier work by the Environmental Protection Agency (EPA). This shows that, with a tax of €20 per tonne of CO_2, Irish emissions by 2010 would be almost 12 percentage points above the limit (which is itself 13% above the 1990 level).

7. The emissions of carbon dioxide are net of emissions from aircraft, but only emissions from international flights are excluded under the accounting conventions for the Kyoto protocol.

4 Effects of a Carbon Tax on Emissions

The two fiscal instruments considered in this report are carbon taxes and tradable emissions permits. In the case of carbon taxes, they are levied as an excise tax on fossil fuels, with the rate of tax being related to the carbon content of the fuel. Emissions permits grant the right to emit a unit of greenhouse gases, here taken to be carbon dioxide. Where the permits are traded, their market price represents the opportunity cost to the owner of using that permit. Where the price of a permit is identical to the rate of tax on the same quantity of carbon dioxide, the incentive effects for consumers will be identical.

Under conditions of certainty about costs and benefits, the tradable permit system can be equivalent in efficiency terms to a price-based system. The difference between the two instruments is the degree of certainty about the cost of emissions to consumers and the degree of certainty about the exact level of emissions in the future.

In the case of a tax, the future price (tax) can be specified well in advance, so firms can plan their future output accordingly. However, the government, in choosing the future tax rate, has to rely on economic analysis to choose the appropriate rate to produce a given reduction in emissions. This results in uncertainty about whether an exact level of emissions will be achieved by a particular date.

In the case of tradable permits, the legal requirement to have a permit before emitting greenhouse gases ensures that the target level of emissions is achieved with a high degree of certainty. However, to forecast the future price of the permits, firms also have to rely on economic analysis. This transfers the uncertainty to the firms covered by the permit regime.

In this report, we do not consider these issues concerning uncertainty so that the economic effects of carbon taxes and tradable permits can be considered as being interchangeable. We examine the effects of an illustrative tax of €20 per tonne of CO_2. We treat tradable emissions permits costing €20 per tonne of CO_2 as having the same effect as a tax at the same rate. Because uncertainty about future prices can affect investment decisions, the resulting simplification may result in some underestimation of the negative effects of tradable permits on investment.

While a carbon tax was assumed in the benchmark forecast described in Section 3 above, in this section we measure the effects of a tax (or tradable emissions permits) compared to a baseline without such taxes or permits.[8] In our simulations, we assume that a tax of €20 per tonne of CO_2 applies to all sectors of the economy from 2005 and that it is indexed to energy prices after 2005 (+2.5% a year).[9] Individual fuel prices are adjusted for the CO_2 emission rate associated with that particular fuel to estimate the effect the imposition of a carbon tax would have on prices. The total tax revenue from the carbon tax can be calculated using forecasts of total CO_2 emissions.

Our forecast of the impact of such a tax (cost of permits) on energy prices, demand and ultimately CO_2 emissions rests on results from the electricity sub-model described earlier. That sub-model examines how the economic ranking of different technologies would be affected by a carbon tax.

Firstly, Moneypoint, a coal-burning power station, would remain on full power over the forecast horizon, in spite of the carbon tax. At current fuel prices, coal is the cheapest base load plant, even if we allow for the capital cost of flue-gas desulphurisation (Table 2.1). Peat-fired generation is assumed to end in 2010. Oil-fired generation is assumed to end in 2005. Finally, as the cost of generating electricity from fossil fuels increases, due to the introduction of a carbon tax, the economics of wind power are enhanced so that renewables are likely to account for 15% of electricity demand by 2010. This is inclusive of the renewables built under the current subsidy programme. To allow such high wind penetration there would have to be increased deployment of open cycle gas turbines (OCGTs), which have a relatively low

8. If such policy measures were not taken, then the benchmark forecast would have to be adjusted by subtracting the effects shown here.
9. Though it is likely that the tax would be phased in gradually.

capital cost and which provide the flexibility to balance the system when the wind drops.

If a carbon tax were levied in 2005, it would significantly increase the price of energy for all consumers in Ireland. Table 4.1 gives estimates of the implied percentage change in the price of different forms of energy consumed by the different sectors of the economy.

The percentage increase in the price of energy consumed by the household sector would be smaller than that for other sectors, because of the substantial distribution margin incorporated into the price. The percentage increase for the electricity sector would be highest because that sector buys energy in bulk, with a resulting very low distribution margin. The biggest increase in price would occur for peat and coal because they have very high carbon contents per unit of energy.

These price changes would signal to the private sector the need both to economise on energy use and to switch to less polluting fuels. As outlined above, we have developed a model of energy demand and emissions that incorporates estimates of the sensitivity of energy demand to price changes. The model captures reasonably well the possibility that individuals and firms will respond to price increases by economising on energy use. For the power generation sector, the special model estimates the likely degree of fuel switching in response to changes in relative fuel prices, as described above. However, outside the power generation sector the model will tend to underestimate the possibility of fuel switching in response to changes in relative fuel prices because of problems in estimating such elasticities of substitution.[10] Such elasticities of substitution have been estimated for Belgium and are incorporated in the Belgian HERMES model (Bossier *et al*., 2000). They would indicate that some additional fuel substitution could be expected over and above that assumed in this analysis.[11]

This means that the model results will tend to underestimate the long-term environmental benefits from a carbon tax, while also slightly exaggerating its economic cost. However, over a medium-term time horizon this underestimation is not likely to be very great.

The increase in the price of energy will have an impact on the overall consumption of energy, while changes in relative energy prices will alter the fuel mix in consumption. Table 4.2 presents our estimates of the implied reduction in consumption of different fuels by the different sectors of the economy.

The fuel mix of the energy transformation sector would be most affected by the introduction of a carbon tax. The overall impact of a carbon tax of €20 per tonne of CO_2 would be to reduce fuel consumption in the electricity sector by over 2% relative to the base case.

10. The sample period used for estimation includes a number of very significant changes which drove the choice of fuel, for example the deployment of natural gas and the regulation of coal use in urban areas. These changes dominate the effects of changing fuel prices making it impossible to estimate a response to changes in relative fuel prices.
11. The elasticities for Belgium are not directly comparable to those for Ireland because of differences in model structure. The Belgian elasticities of demand for the different fuels are quite low, with the exception of that for coal. In the case of coal, the Belgian results suggest significant substitution of gas and oil for coal in the productive sector of the economy in the face of changing relative prices. Generally, these elasticities would suggest that there would be some additional fuel substitution in the Irish case, especially in the case of solid fuel. This could enhance the potential emissions reductions compared to the results shown here. However, because of the current relatively low share of solid fuel in final energy demand, these additional benefits would not greatly alter the conclusions of this report.

Table 4.1. Change in energy prices in 2005 for a carbon tax of €20 per tonne of CO_2.

Sector	Household, %	Industry, %	Transport, %	Power generation, %
Fuel				
Coal	22.1	88.0		131.7
Oil	11.4	15.5	5.3	34.7
Gas	11.1	23.2		31.9
Peat	30.1			84.9
Electricity	4.4	6.8		
Total	14.3	26.2		77.1

Table 4.2. Change in consumption of fuels in 2010 for a carbon tax of €20 per tonne of CO_2, % change compared to base case.

Sector	Household, %	Industry, %	Transport, %	Power generation, %
Fuel				
Coal	–3.3	–59.1		0.0
Oil	–3.4	4.3	–1.7	–100.0
Gas	–3.3	–4.6		45.7
Peat	–3.3			–100.0
Electricity	–2.2	–3.6		
Total	–3.1	–4.3	–1.7	–2.2

The consumption of coal in this sector is likely to be unchanged relative to the base case, despite the large price increase. Operating Moneypoint on full power remains the most efficient choice (excluding renewable fuels), even when the cost of flue-gas desulphurisation is included. It is only if the tax rose significantly further to €30 per tonne of CO_2 that it would be likely to close.

The full long-run marginal cost of providing a unit of electricity includes the cost of capital as well as fuel and operating costs. In the case of an existing plant, the cost of capital is zero; it is a sunk cost. However, a new gas plant will only be built if the price will remunerate the cost of capital. In the case of oil, even without a tax, if relative fuel prices were to remain at their 2001 level, oil would be likely to be phased out over the next decade. Oil-fired plant could still be used to provide adequate margin (and security of supply) in the case of failure of other plant, but the imposition of a tax of €20 per tonne of CO_2 would result in the closure of all oil-fired plant.

Existing peat-fired plants (excluding the newest plant) have the highest long-run costs both before and after the introduction of a carbon tax (see Table 2.1).[12] By replacing old peat stations with new gas-fired stations it would be possible to reduce both costs and emissions compared to keeping existing plant in operation (or compared to new peat-fired plant). Of course, other requirements of national policy may restrict the ability of the electricity sector to react to the price signals by minimising its costs and closing peat-fired plant. In particular, a continuing requirement to use peat-fired stations would increase the cost of electricity compared to our simulations, increase emissions, requiring more expensive emissions reductions elsewhere, and adversely affect GNP. However, if it is required to keep peat stations in operation for reasons of national policy, the replacement of the old plant by new plant makes sense.

Total consumption of energy by households is likely to fall by over 3% by 2010 compared to the base case. As mentioned above, the rise in energy prices will lead to a substitution away from energy use by households, but the elasticity of substitution between energy and other goods is quite low. This indicates that overall consumption of energy by households will only fall by a small amount, despite increases in the price of energy. The process of substituting gas and oil for coal and turf that has been witnessed over the past 15 years is likely to continue. Rising affluence, changing lifestyles, technical change, government discouragement of the use of 'dirty fuels' and the introduction of natural gas have led to a move towards central-heating boilers rather than open-fire heating. The relative increase in the prices of coal and peat will further contribute to the substitution process. The model suggests a bigger response from the industrial sector by 2010. This mirrors the findings for Belgium of Bossier *et al*. (2002).

Consumption of energy in the industrial sector is likely to be over 4% less in 2010 than it would have been if no tax were introduced. This fall in the consumption of energy would take between 5 and 10 years. In addition, the extent of the reduction depends on whether the price of energy increases throughout Europe. The sensitivity to once-off price increases is derived from the experience of the 1970s and the early 1980s where industry in all

12. This issue was discussed in Nic Giolla Choille (1993).

countries faced a huge rise in costs. Implementing the fruits of this research took many years and the same would be true today for a major increase in prices. The largest percentage changes in the consumption of various fuels are for the fuels whose relative prices have increased the most.

In the industrial sector, we are assuming that there is still coal consumption amounting to 235,000 tonnes in 2010, accounting for 0.70 million tonnes of CO_2. However, it may well be economic for the few firms using this fuel to switch out of it. In addition, some of these firms may in any event receive special treatment under EU regulations. If this is the case, part of any voluntary agreement should involve a complete shift out of coal.

Because of the heterogeneity of the industrial sector, there may be a few sub-sectors that are particularly adversely affected by the price rises (see Boyle, 2000 and Indecon, 2002). These sub-sectors are likely to receive special treatment because of the adverse potential impact of a carbon tax on their competitiveness. If they were to close as a result of the tax and move elsewhere there would not necessarily be a significant gain for the global environment. As a result, it makes sense to consider special treatment of sectors that have a very high-energy dependence **and** which are subject to significant competition. However, if action is taken at an EU-wide level the number of such sectors will be further limited to those that are subject to competition from outside the EU. Such special treatment would obviously reduce the likely reduction in emissions by the sector.

The increase in government revenue from the carbon tax would be likely to amount to around €850 million or approximately 1.0% of GNP in 2005. Figure 4.1 compares the forecast for GHG emissions on unchanged policy with the forecast for emissions when there is a tax on carbon dioxide. By 2010, the decline in energy use due to the imposition of the tax would result in a reduction in CO_2 emissions of around 3.3 million tonnes.

This decline (3.3 million tonnes) in emissions of CO_2 would represent a reduction compared to the benchmark figure for 2010 of around 6.6%. In a similar exercise for Belgium, Bossier *et al*. (2002) estimate that a tax of €31.50 at 1999 prices, roughly €35 at 2003 prices would reduce Belgian emissions in the medium term by around 10%. This would suggest that the cost of abatement is higher in Ireland than in Belgium.

On the basis of our forecasts, GHG emissions would rise to around 22% above 1990 levels by 2010 even with the introduction of a carbon tax from 2005 onwards (see Table 3.6). This assumes no change in emissions from industrial processes.

This would still leave Ireland significantly above the limit of 13% above 1990 levels agreed as part of the

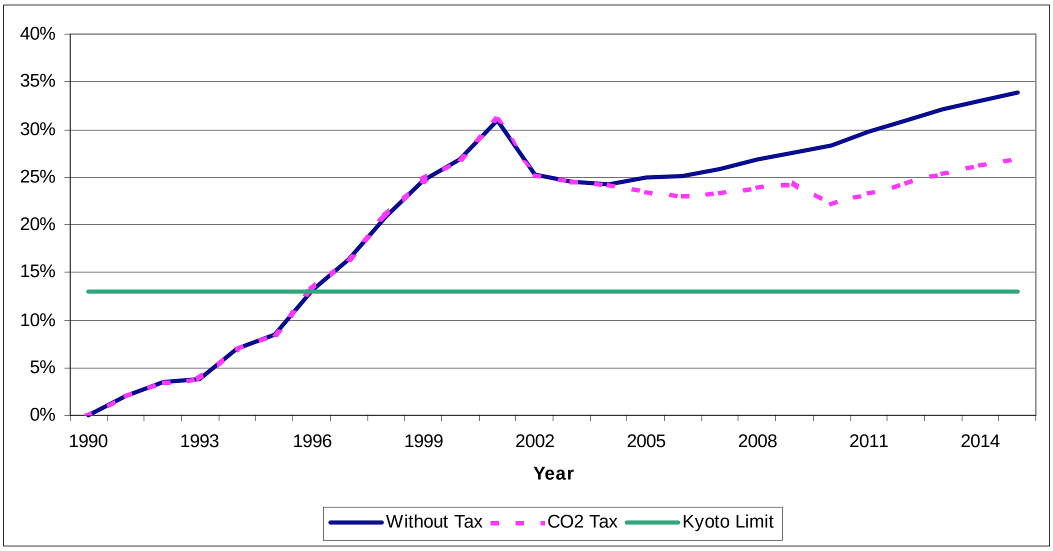

Figure 4.1. Greenhouse gas.

Kyoto protocol. However, the effect of the carbon tax would be to move Ireland much closer to the target, leaving a more limited contribution to be made by other policy measures or by flexible mechanisms under the Kyoto protocol.

Figure 4.2 shows the contributions to the 3.3 million tonnes reduction in CO_2 from the different sectors. The biggest reduction is made by the electricity sector –2.4 million out of the 3.3 million tonnes. When this reduction is distributed over the energy-consuming sectors according to electricity use, the pattern of reduction is as shown in Fig. 4.2. This indicates that the largest reduction (including electricity consumed) would come from the industrial sector with a very small reduction occurring in the transport sector.

The model assumed that a sector's reduction in emissions is chosen on an efficient basis. This suggests that the cheapest reductions in emissions from energy use are to be achieved in the electricity sector. After that, the industrial sector, subject to the caveats above, has the next biggest opportunity to achieve reductions at a reasonable price. For the transport sector other types of policies will be needed if significant reductions are to be achieved at a reasonable cost. Of these possible policies, EU-wide regulations on the energy efficiency of motor vehicles and the development of urban public transport in Ireland may offer the best possibilities.

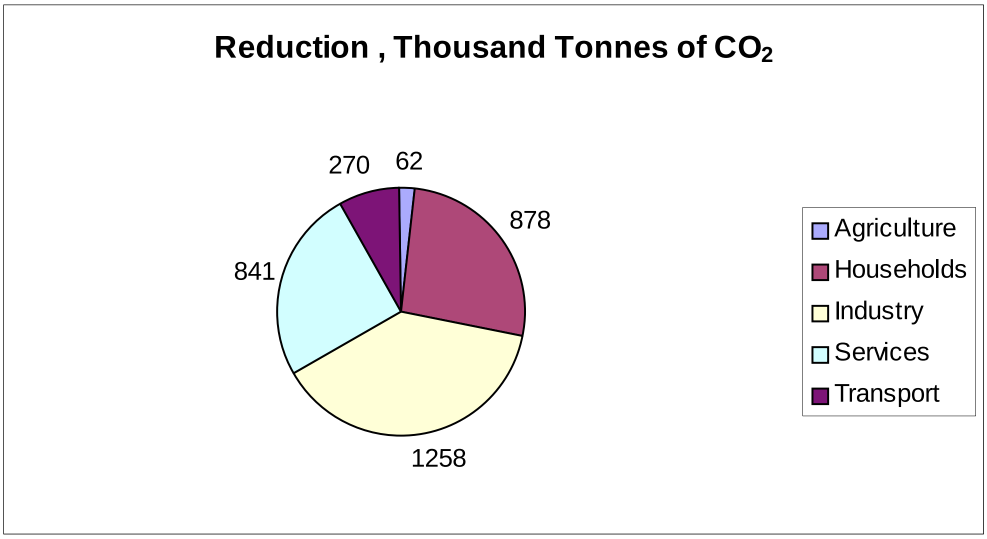

Figure 4.2. Contribution to reduction in CO_2 emissions by sector.

5 Macro-Economic Effects

In this report, we have considered the case where Ireland acts on its own in tackling the problem of climate change. This means that the competitiveness loss from domestic policy action is maximised. In practice, the task of complying with the Kyoto protocol will impose burdens on all EU members (and other signatories). The policy response elsewhere, even if it is not co-ordinated by the EU, will in all probability involve use of fiscal instruments similar to those discussed in this report. As a result, the rise in costs elsewhere could be similar to (or even greater than) those in Ireland, ensuring a more limited competitiveness effect from rising input costs. It is only in the case of emissions-intensive business competing on a world market that such competitiveness effects will remain important. Thus, the results presented here could prove to be an upper-bound estimate of possible damage from the fiscal measures.

5.1 Economic Theory – Incidence

In considering the impact of a tax on carbon emissions (or tradable emissions permits), the first issue is where the incidence of the tax will lie. In the case of all taxation, the person who signs the cheque is not necessarily the person who ultimately pays the tax. The standard result on tax incidence is that the tax burden will be shared by producers and consumers, depending on their relative elasticities of supply and demand. In the case of firms in the tradable sector in Ireland, there is evidence that they are price-takers on world markets (Callan and Fitz Gerald, 1989). In this case, the tax cannot be passed on to consumers in the rest of the world and the effect of a tax is to depress profitability in the sector in Ireland. In turn, this loss of competitiveness reduces output and employment, also putting downward pressure on wage rates. Therefore, some of the incidence of the tax which falls on these firms ultimately falls on those who lose their jobs, or experience lower wages as a result.

The effects of a carbon tax (tradable emissions permits) will depend to a significant extent on whether it is introduced in Ireland alone or whether it is part of a wider European policy initiative. If introduced unilaterally it seems likely that the tradable sector, covering much of manufacturing, would not be able to pass on the tax to consumers abroad or in Ireland. The result would be a loss of profitability and lower output. The extent to which the tax can be passed backwards to other inputs into the production process, especially labour, will depend on how the labour market works.

For firms in the electricity sector facing inelastic demand and no competition from outside the EU, the situation is different. In this case, the cost of the tax or permits can be passed on as higher prices. This may also apply to one or two other sub-sectors covered by emissions trading.

For the services sector, it is easier to pass on price increases in inputs and it is assumed that this is what would happen in the case of a carbon tax. Thus, while the household sector only accounts directly for around a quarter of carbon emissions, they may ultimately carry a significantly higher share of the burden through higher prices for the non-energy products that they buy, through lower wage rates or through a loss of employment.

In modelling the impact of the carbon tax, much will depend on how the labour market reacts. Over much of the last 30 years, the supply of labour in Ireland has been very elastic in the long run because of the possibility of migration. High unemployment tended to lead to emigration and, in the 1990s, there was very substantial immigration to meet rapidly rising demand. Under these circumstances, the sub-model of wage formation in the HERMES model implies that the bulk of any tax on labour (income tax or social-insurance contributions) will be passed on to employers. Conversely, the bulk of tax cuts are also passed on to employers in the form of lower wages. This reflects the fact that employees bargain in terms of real after-tax wage rates. The institutionalisation of this in the partnership process is a reflection of the reality of the labour market.

The result of this model is that a loss of competitiveness suffered by the tradable sector cannot be passed back as lower wage rates. Instead, it is likely to be observed as a fall in employment as more marginal firms close. This key relationship in the model is very important in determining how the economy would respond to a carbon tax and who would end up ultimately footing the bill.

In more recent years, infrastructural constraints have made Ireland more and more expensive as a location for mobile labour. The more Irish people or foreigners who come from abroad to Ireland, the higher will be the price of accommodation and the greater the congestion. In turn, this makes relocation to Ireland increasingly unattractive. As discussed in McCoy *et al.* (2000), this has probably made the supply of labour less elastic. The implication of this is that, in the future, some of the incidence of a carbon tax affecting the tradable sector may be passed back as lower nominal wage rates.

In the modelling work discussed below, we have used the version of the model that was estimated over the 30-year period 1970–1999 when labour supply was very elastic. To the extent that the labour market has changed, more of the incidence of the tax would be carried by households through lower wage rates than through lower employment.

5.2 Economic Theory – Efficiency

Most taxes involve distorting the economy and a resulting loss of economic efficiency with the exception of cases where externalities exist, where a tax can guide the market to the socially efficient outcome, e.g. optimal environmental taxes. Under these circumstances, the value of the marginal unit of public expenditure also has to be high to warrant raising more taxation. For example, a tax on employment (income tax or social-insurance contributions), which pre-empts a proportion of every euro earned, reduces the incentive to work, leading to either or both lower labour supply and higher wage rates for employers. In raising revenue through this channel, there is a corresponding loss of output representing the ‘excess cost’ of the tax raised. This loss is additional to the reduced income available to the taxpayer due to the direct payment of the tax.

This loss of efficiency is reflected in the marginal cost of public funds, which is substantially greater than the value of the tax raised. As shown in Honohan and Irvine (1987) when tax rates were very high in Ireland in the 1980s this marginal cost was correspondingly high. With falling tax rates over the 1990s this cost has fallen (Honohan, 1998). However, it is still significantly greater than unity – there is an efficiency loss over and above the revenue raised.

The optimal carbon tax would be one that equates marginal abatement costs and marginal environmental damages. This would achieve economic efficiency. A desirable outcome would be if the tax caused a small loss of output combined with a major reduction in emissions through a range of different cheap mechanisms, such as fuel switching, increased efficiency and new technology.

In considering the case of carbon taxes (or emissions trading, where the permits are auctioned), the tax revenue accruing to the government does not just ‘disappear’. It is available to be used in a range of different ways. In using the revenue, the government can aim to get added value by using it to reduce taxes and related distortions elsewhere in the economy. It is possible that the social cost of the taxes that are reduced could be greater than the social cost of the environmental taxes, in which case there would be a net benefit to the economy.

Here we consider five stylised approaches to using the revenue:

1. Repaying debt.
2. Reducing social-insurance contributions.[13]
3. Reducing VAT.
4. A lump-sum payment to adults or households.
5. Grandparenting emissions permits rather than auctioning.[14] If firms can pass on the cost of emissions permits to consumers then this is equivalent to a lump-sum payment to the shareholders of the firms granted permits. However, where firms trade on world markets and cannot pass on the cost, their emissions become liabilities against which the permits have to be set. The net position of the firm is unchanged. Therefore, the critical issue is the ability of firms to pass on the cost in the form of higher prices to consumers.

13. The effect of using the revenue to reduce income tax was also simulated. The results are similar to the scenario where social-insurance contributions are reduced and so are not presented in this report but are available from the authors.
14. Grandparenting is the phrase used where the right to pollute is conferred on existing polluters.

The simplest example of using the revenue is the case where the government is assumed to reduce debt or build up assets. Three of the other four approaches to using the revenue considered here involve reducing taxes[15] and the fourth involves the government forgoing possible revenue.

Using the revenue to repay debt obviously has no benefit in terms of reducing current distortions from other taxes in the economy, though it yields benefits in the future. In the longer term, the reduction in interest payments (or increase in receipts) allows for lower levels of taxation to fund a given level of public expenditure. In the case of Option 2 above, it is assumed that the revenue is used to reduce social-insurance contributions. As discussed above, this will have the effect of reducing distortions in the labour market. The model indicates that a reduction in the tax burden on employees finds its way into more moderate wage settlements, enhancing competitiveness. In turn, this results in higher output, adding to the increased disposable income arising from the tax reduction on its own.

However, there is reason to believe that this pass through of lower taxes into moderate wage settlements was modified under the tighter labour market of the last 4 years (McCoy et *al*., 2000). The result is likely to be a much smaller output gain from reducing taxation than was the case in the 1980s. As a result, the simulations may exaggerate the beneficial impact from the tax reduction.

Using the revenue to reduce social-insurance contributions has a marginally greater positive effect on the labour market than if the revenue were applied to reducing income tax. While much of the revenue from income tax comes from earned income, there is also a substantial amount due from unearned income. In the latter case, there are likely to be no positive labour-market effects. By using the revenue to reduce social-insurance contributions, all of it impacts on the labour market, having a marginally greater direct effect on competitiveness and output.

15. It would also be possible to consider using the revenue to fund increased expenditure. In that case, the issue would be whether the marginal benefit from the increased expenditure would offset the loss from the imposition of the environmental tax.

In the case of Option 3, the reduction in VAT, by reducing the price level, there is also a substantial effect through reducing nominal wage rates. However, the benefits of a cut in VAT are likely to be less than in the case of a cut in income tax because the benefit would flow to those outside the labour market, as well as to those in the labour market. As discussed later, this could be advantageous in equity terms, but would be likely to have less beneficial output effects.

The fourth option of a lump-sum transfer (tax rebate) to all adults or all households is favoured by some environmentalists, and has beneficial income distribution effects. However, it would do nothing to reduce the distortions from the existing tax system and would, as a result, be much less beneficial in terms of the ultimate impact on output and income (GNP).

The fifth option is to grant emission permits to existing firms. If a tradable emissions regime is implemented in the EU, and Ireland participates fully in it, then all participating firms will have to acquire permits for each tonne of carbon-equivalent fuel that they import. If they are granted these permits free through a grandparenting process, they will be free to either use the permit to buy fuel, to sell the permit within Ireland, or to sell it outside Ireland to other businesses. If a firm is trading on global markets, then their output price will be determined by the world price of competing firms and they will not be able to pass on the cost of permits exhausted in the production process as higher prices.

However, the electricity sector, the largest sector covered by the EU trading regime, differs from others where output is traded on world markets. In the case of electricity, the elasticity of demand is low and there is no competition from supplies outside the EU. Under these circumstances, with pricing based on marginal cost, if the holders of the permits choose to continue to generate electricity in Ireland, they will then charge Irish consumers the usual price for the energy they import **plus** the price they could get for the emissions permit on the EU market.[16] Therefore, the bulk of the incidence of the carbon tax will fall on the consumer, and the shareholders in the generating companies will receive a windfall gain equal to the value of the grandparented permits.

Under these circumstances, the ultimate incidence of the value of the permits given away free to the key sectors producing for the domestic market will be on the household sector. That sector will have to pay the higher price for goods to remunerate the value of the permits. However, because the permits are given away free, there will be no revenue to provide compensation to the household sector and there will be no revenue available to reduce distortionary taxes elsewhere in the economy. This mirrors the case of Option 4 where lump-sum payments are made to households.

There will also be possible distortionary effects arising from the nature of the grandparenting process. The allocation of the permits to electricity generators will, as discussed above, represent a windfall gain to those who receive them. That windfall gain will reduce the cost of capital for those firms, while leaving unaffected the cost of capital for renewable generation, distorting the market. For new entrants, the potential gain from an allocation of permits would also reduce the cost of capital, providing an incentive to over-invest. If such new entrants received no such allocation then they would be disadvantaged relative to incumbents, helping protect inefficiencies in existing generating plant. These additional potential costs, arising from the grandparenting process distorting market prices, are not taken into account in the simulations shown in this report.

This option of grandparenting emissions permits differs from making lump-sum payments to households in terms of its distributional effects. It will confer benefits only on shareholders in firms that are significant emitters of greenhouse gases and are included in the trading regime. In addition, this scheme could provide barriers to entry for new firms, leading to monopolistic pricing and a resulting further welfare loss.

These distributional differences will also have real economic side effects. A significant number of the firms likely to be included in grandparenting of allowances are owned by foreign shareholders.[17] In the case of foreign shareholders, the grandparenting of allowances will see a transfer of resources from the domestic household sector to the foreign shareholders. This reduction in domestic purchasing power will reduce domestic output.

As a result, on *a priori* grounds, with the exception of the case where revenue is used to repay debt, the macro-economic effects of the different options are likely to be ranked in the order shown: Option 2 is likely to be most positive (least damaging) for the economy and Option 5 is likely to be least beneficial (most damaging).

5.3 The Macro-Economic Effects

The macro-economic effects of a carbon tax of €20 per tonne of CO_2 were examined using the HERMES model of the Irish economy. In carrying out the analysis, we examine a range of different assumptions concerning how the additional revenue accruing to the government is deployed.

The results from the energy sub-model feed through into the macro-economy through the effects on prices of energy and also through the revenue raised from the tax. The increased price of energy affects consumer prices directly. However, in the tradable sector it adversely affects competitiveness. This loss of competitiveness causes a loss of output and employment. In the services sector, the bulk of the price increase is passed on as higher services prices. Wage rates react to changes in both prices and direct taxes. This latter channel means that the initial impact of the higher energy prices is magnified by the response of wage rates.

The effects of recycling all of the revenue from the tax through the five optional mechanisms outlined are examined using the HERMES macro-economic model. The simplifying assumption is made that the tax is introduced at the full rate of €20 from the beginning of 2005. Because the economy will take some time to react to the resulting price changes, we consider the cumulative effects of the policy change in Year 1 (here assumed to be 2005), Year 2, Year 5 and Year 10. At the

16. In a competitive market, shareholders will require management to maximise the return on all assets employed in the firm. Emissions permits granted to a firm will be an asset (assuming they can pass on the price to consumers) with the price determined on the EU market where they are freely sold. To get the return on this asset, the output price will have to rise to produce the appropriate return. In a competitive market it will, therefore, make **no** difference to the price whether the permits are auctioned or granted free (grandparented) to firms.

17. Many of the Irish firms affected will also have significant foreign shareholding.

end of this section, we discuss the effects of using 23% of the revenue from the carbon tax (as discussed in Scott and Eakins, 2004) to either increase welfare payments to compensate low-income households or to invest in energy-saving improvements to produce a permanent improvement in the welfare of such households.

As shown in Table 5.1, if the revenue is all used to repay debt, the effects of the tax will be to reduce the level of GNP by a maximum of around 0.36 percentage points in the medium term. However, as the debt is repaid (or assets built up) this reduces government interest payments. The model makes the simplifying assumption that there are fully integrated capital markets in Europe so that, at the margin, foreigners own all new debt. Thus, foreign debt interest repayments fall with the falling debt. This means that the loss of GNP is reduced after 2010. However, the loss of GDP stabilises in the longer term at almost 0.3 percentage points below the baseline (Fig. 5.1) with the wedge between the two being the reduced foreign debt interest payments.

The carbon tax would result in an increase in energy prices for all sectors. The impact on consumer prices would be just under half a percentage point in the first year (Table 5.1). This includes the knock-on effects of higher inflation on wage rates as employees bargain to protect their real after-tax remuneration. The ultimate effect would be to raise the price level by around 0.5 percentage points above the baseline. Because employees bargain in terms of the real after-tax wage, the result would be a rise in wage rates in the long term of 0.4 of a percentage point compared to the benchmark. This would still leave employees slightly worse off in terms of real after-tax wage rates. The adverse effects on competitiveness would then include not only the higher energy prices, but also the higher wage rates. It is this broad effect on competitiveness that explains the loss of output measured by GDP and GNP.

As shown in Table 5.1 the higher saving (lower borrowing) by the government has a counterpart in a permanent increase in the balance of payments surplus. This reflects the continuing improvement in the government's net foreign asset position.

However, the relatively favourable medium-term public finance position of the government sector means that the most appropriate assumption is that the government would recycle the revenue in such a way as to leave the exchequer borrowing (saving) as a share of GNP unchanged from the benchmark. We now consider the differing effects of recycling the revenue through the four instruments identified above. In the case of the lump-sum payment to households (or individuals), households on low incomes will be more than compensated for the higher prices and no provision is made for welfare increases.

If the additional revenue from carbon taxes were recycled through reducing social-insurance contributions, the tax cuts would impact on the economy in two ways. Firstly, real personal disposable income would be boosted and consumption would increase. Secondly, because employees are assumed to bargain in terms of after-tax wage rates, the tax reductions would result in a fall in nominal wage rates, improving the competitiveness of the tradable sector. The model results suggest that the competitiveness gain from the cut in social-insurance contributions would more than offset the loss from the carbon tax, leaving the level of GNP slightly up on the benchmark. Of course, for some energy-intensive sectors, the gain from lower wage costs would not be enough to offset the loss from higher energy prices.

Table 5.1. Effects of using revenue to repay debt, change compared to base.

Year	1	2	5	10	Average to 2015
GNP, %	–0.29	–0.36	–0.36	–0.33	–0.31
Employment, %	–0.17	–0.25	–0.36	–0.29	–0.24
Consumer prices, %	0.48	0.46	0.44	0.5	0.53
Wage rates, %	0.48	0.35	0.28	0.39	0.45
Real after-tax wage rates, %	–0.61	–0.76	–0.82	–0.81	–0.87
Balance of payments, % of GNP	0.17	0.27	0.23	0.19	0.22

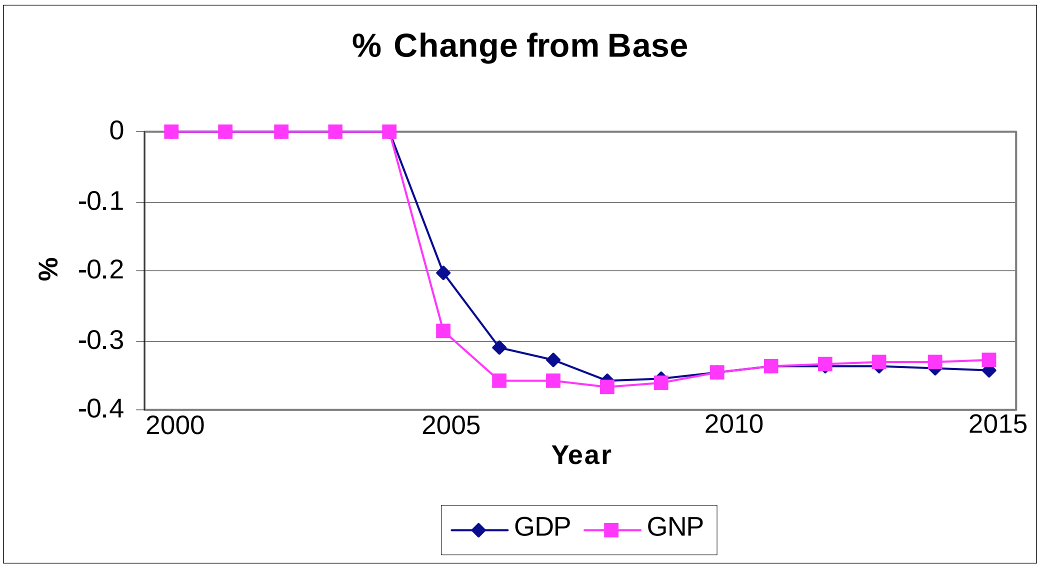

Figure 5.1. Effects on output of a carbon tax with repayment of debt.

However, the losses by such firms would be more than offset by the gains of the bulk of the business sector.

The price level would fall by around 0.33 percentage points in the first year, and this disinflationary impact would be strengthened in the long term by the reduction in labour costs. Real after-tax wage rates would initially fall by around 1.5 percentage points, but the long-term effect would be a smaller decrease of 0.8 percentage points. As shown in Table 5.2, in the medium term there would be a significant positive effect on employment.

The long-term effects of this combination of measures would be to leave the levels of output, income and employment little changed from the benchmark level, while at the same time a significant reduction in carbon emissions would be achieved.

The second option for recycling the revenue considered here is a reduction in the rate of VAT. The VAT reduction would more than offset the effect of carbon taxes on the level of consumer prices, leaving the price level 1.5 percentage points below the benchmark in the first year. In the medium term, the price level would settle at around 0.6 percentage points below the benchmark. The effect of this would be to reduce nominal wage rates in the first year by over one percentage point. In the longer term, the impact on real after-tax wages would be small, though nominal wage rates would remain below the benchmark, resulting in some gain in competitiveness. However, the gain would not be sufficiently large to offset the negative effects of the carbon tax, leaving permanent GNP around its benchmark level (Table 5.3).

The major reason for the difference in the macro-economic effects of recycling the revenue from the

Table 5.2. Effects of recycling revenue through reduced social-insurance contributions, change compared to base.

Year	1	2	5	10
GNP, %	0.19	0.2	0.12	0.02
Employment, %	0.49	0.36	0.33	0.02
Consumer prices, %	–0.33	–0.27	–0.24	–0.18
Wage rates, %	–1.51	–1.22	–0.98	–0.83
Real after-tax wage rates, %	0.42	0.57	0.36	0.02
Balance of payments, % of GNP	–0.14	–0.27	–0.11	0.03

Table 5.3. Effects of recycling revenue through reduced VAT, change compared to base.

Year	1	2	5	10
GNP, %	0.24	0.07	0.07	0
Employment, %	0.07	–0.03	–0.12	–0.07
Consumer prices, %	–1.49	–0.43	–0.68	–0.56
Wage rates, %	–1.21	–0.34	–0.52	–0.46
Real after-tax wage rates, %	–0.01	0	–0.03	–0.09
Balance of payments, % of GNP	0.01	–0.08	–0.02	–0.04

Table 5.4. Effects of recycling revenue through lump sum to households, change compared to base.

Year	1	2	5	10
GNP, %	0.02	–0.03	–0.34	–0.51
Employment, %	0.09	0.32	0.40	–0.17
Consumer prices, %	0.57	0.76	0.87	0.47
Wage rates, %	0.55	0.70	0.85	0.32
Real after-tax wage rates, %	1.00	1.24	0.95	–0.17
Balance of payments, % of GNP	–0.44	–0.66	–0.59	–0.12

carbon tax by social-insurance contributions and by VAT is that more of the benefits of lower social-insurance contributions go to employees than those of a VAT cut, since many beneficiaries of a VAT cut are not in the labour market. Thus, the positive labour-market effects are higher, with a consequential larger gain in competitiveness and in employment. The corollary of the more dispersed distribution of the benefits is that the use of VAT would be more progressive in its effects on the distribution of income than would be the case of a cut in social-insurance contributions spread evenly over all taxpayers.[18]

The third option for recycling revenue considered here is the payment of a lump sum to all households (or all adults). In this case, it is assumed that there is no need for compensation of those on low incomes through welfare payments because the lump-sum payment would more than compensate for the direct costs of higher energy prices. On the face of it, looking at the impact effect in Year 1 in Table 5.4, this would seem to be a favourable option. However, this is deceptive because this beneficial impact effect is not sustainable. All of the transfer goes to households and the 'feel-good' factor would see a major increase in consumption and housing investment, the latter partly funded by borrowing.[19]

In addition, there would be no favourable labour-market effects as the payment is assumed to be paid independent of labour-market status. As a result, there would be no competitiveness gain to offset the effects of the carbon tax. By Year 5, the negative competitiveness effects would begin to bite and output would be significantly below the baseline. Output in the traditional manufacturing sector would eventually settle around 1 percentage point below the benchmark. There would also be a fall in employment in the long term of almost 0.2 percentage points.

The cumulative effects of the loss of competitiveness would be that in the long term the level of GNP would be around 0.5 percentage points below the benchmark, a much less favourable outcome than for the case of a cut in social-insurance contributions or in VAT. This less favourable outcome reflects the fact that this way of recycling revenue leaves the distortionary effects of

18. Obviously, suitable targeting of cuts in income tax could ensure that those in the lower half of the income distribution gained more. However, those on the lowest incomes are not taxpayers – hence the allocation for increased welfare payments.

19. This 'feel-good' effect depends on consumers' expectations about the future, and unfavourable external circumstances could permanently affect such expectations, resulting in a much smaller short-term gain.

existing taxes unchanged. While the distributional effects would be much more equitable, these benefits would be bought at a significant cost in terms of lost output (Table 5.4).

The final method of recycling considered here is the case where emissions trading permits are grandparented rather than auctioned. This involves the payment of a 'benefit in kind' to the company sector – the granting of the permit. Because the permits can be traded they can easily be converted into cash.

While firms are granted the permits free, as discussed above, market forces will see prices fully adjust to reflect the cost of the permit for firms that do not trade on world markets. This will mean that the shareholders in the companies receiving the permits will receive a double benefit – the value of the permit together with full compensation through higher prices. The windfall gain represented by the permit will not carry any incentive effects to increase output or employment, and will eventually be paid out to shareholders as higher dividends.

In addition, if the market is not fully competitive, the granting of the permits on the basis of historic emissions may well help protect incumbent firms, resulting in reduced competition and higher costs for consumers. This could aggravate the negative effects of this scenario. If all shareholders lived in Ireland, the ultimate macroeconomic effects of recycling revenue in this way would be rather similar to those from a lump-sum payment to households, though the income distribution effects would be very different. However, as indicated above, because many of the ultimate beneficiaries would be foreign shareholders in companies receiving permits, much of the benefits of the recycling of the revenue would flow out of Ireland as profit repatriations. As a result, this option would have the most unfavourable long-term effects on the Irish economy of any of the options considered here. The average loss of GNP would be over 0.3 percentage points over the period to 2015, with no prospect of any improvement in the situation in the longer term (Table 5.5).

The effects of the five different scenarios (including the debt-repayment scenario) are shown in Table 5.6, which shows a clear ranking in the long term for the first three recycling options. Using the revenue to reduce social-insurance contributions actually leads to a very small increase in output. In that case, the increase in output exceeds the increase in output that could be achieved if the revenue were used to cut VAT. The long-term (Year 10) fall in output is much greater with a lump-sum transfer to households. The case of the grandparenting of permits is much worse than any other option when considered over the long term. The estimated loss of

Table 5.5. Effects of recycling revenue through 'grandparenting', change compared to base.

Year	1	2	5	10
GNP, %	–0.29	–0.34	–0.35	–0.32
Employment, %	–0.17	–0.24	–0.34	–0.26
Consumer prices, %	0.48	0.45	0.43	0.48
Wage rates, %	0.47	0.33	0.27	0.38
Real after-tax wage rates, %	–0.61	–0.72	–0.72	–0.63
Balance of payments, % of GNP	0.17	0.26	0.19	0.11

Table 5.6. Effects on GNP, % change compared to base.

Year	1	2	5	10
No recycling of revenue	–0.29	–0.36	–0.36	–0.33
Social-insurance contributions	0.19	0.2	0.12	0.02
VAT	0.24	0.07	0.07	0
Lump sum to households	0.02	–0.03	–0.34	–0.51
Grandfathering to companies	–0.29	–0.34	–0.35	–0.32

output in the long term probably underestimates the negative effect through increased profit repatriations. These estimates also take no account of negative competition effects. As a result, it must be considered the least desirable option on grounds of economic efficiency.

As well as providing a clear ranking of the economic effects of the different instruments, this analysis suggests that the long-term cost to the Irish economy of a carbon tax would be small. Thus, the reduction in emissions achieved through the use of this instrument is likely to be relatively painless at the aggregate economy level. However, for individuals who consume above-average amounts of energy or who are very dependent on solid fuels, the effects may be more adverse.

5.4 Effects of Increasing Welfare Benefits

Scott and Eakins (2004) show that expenditure on fuels constitutes a higher share of income for families on low incomes and so they are likely to be more adversely affected by the imposition of a carbon tax. As a result, we examine the effects of using 23% of the revenue from the carbon tax to either increase welfare payments to compensate low-income households or to invest in energy-saving improvements to produce a permanent improvement in the welfare of such households. Table 5.7 presents the results for the case where the revenue is recycled through reduced social-insurance contributions and the results can be scaled accordingly for the other options. Overall, using 23% of the tax revenue to compensate low-income families has a marginal negative effect on GNP and virtually no effect on employment, compared to the situation where the compensation does not take place.

5.5 Distributional Implications

As discussed above, the tradable sector will probably carry less of the incidence of the tax than would be implied by the sector's current level of emissions as firms in this sector tend to be price-takers. The household sector, by contrast, will carry a higher incidence than its share of emissions would suggest. This is reflected in the fact that, with no recycling of revenue, the household sector will experience a rise in prices of around 0.5%, whereas the direct impact through the price of the sector's energy inputs would suggest a price rise of only 0.25%. In the absence of the recycling of the revenue, the household sector would also experience higher unemployment.

The results highlight the very considerable importance of considering how the revenue from a carbon tax (or potential revenue from tradable emissions permits) is used. If there is no revenue because permits are grandparented then there will be a substantial transfer of resources from the household sector generally to shareholders in the relevant firms, a significant number of whom may live outside Ireland. As the tax (emissions trading regime) will particularly affect poorer households (Scott and Eakins, 2004), the state will face the choice of ignoring the fuel poverty effects of the regime or of having to raise other taxes to compensate poor households. Here we assume that taxes are increased to compensate lower-income households. The choice of a lump-sum payment to households is, on the face of it, very equitable. However, because of its very adverse

Table 5.7. Effects of using 23% of the carbon-tax revenue to compensate low-income families, change compared to base.

Year	1	2	5	10
Without using 23% of revenue to compensate low-income families				
GNP, %	0.19	0.2	0.12	0.02
Employment, %	0.49	0.36	0.33	0.02
Using 23% of revenue to compensate low-income families				
GNP, %	0.16	0.17	0.06	–0.1
Employment, %	0.43	0.37	0.33	0.03

competitiveness effects, it would involve a substantial loss of output in the long term, affecting everyone's income. It would also have the most negative effects on employment, with the incidence of the adjustment falling disproportionately on those losing their jobs.

The combination of a carbon tax with the recycling of the resulting revenue through a reduction in social-insurance contributions, and an increase in welfare payments, appears to be the most efficient way of reducing carbon emissions. While slightly less desirable from an economic efficiency perspective, using VAT to recycle the revenue could have some favourable effects from a distributional point of view.

The mechanism proposed by Scott and Eakins (2004) for ensuring that low-income households are protected from the distributional effects of the carbon tax is akin to the lump-sum transfer option, except that it is confined to those on low incomes and the sum to be transferred is, at a maximum, 23% of the total revenue. This combines the distributional advantages of the lump-sum payment with the economic efficiency effects of the cut in taxation on labour.

6 Conclusions

The economic effects of any carbon tax will depend on whether Ireland introduces the tax (or equivalent fiscal measures) unilaterally, or whether similar measures are taken throughout the EU. In this report, we have generally assumed that Ireland moves alone which means that there is a significant competitiveness loss. However, if, as seems likely, the rest of the EU is taking rather similar measures with similar costs, then Ireland's position *vis-à-vis* its EU neighbours would not be changed. It would only be major energy users competing on a worldwide market that would be affected.

The environmental effects would also be influenced by whether or not the tax was part of an EU-wide policy development. In the case of industry and transport, what is required is significant research and development to produce more energy-efficient solutions. If the price of energy rises in Ireland alone, there may be an incentive for some R&D in Ireland. However, it will be extremely small compared to the volume of R&D that could be expected at the level of the EU. For example, no car company will develop a new more-efficient engine for the Irish market. However, if access to the EU market is conditional on technological advance, it will be sensible for the major car manufacturers to invest significant amounts in R&D.

This analysis suggests that a carbon tax of €20 per tonne of carbon dioxide in Ireland would make a significant contribution to achieving Ireland's targets on emissions reduction under the Kyoto protocol – holding emissions to a limit of 13% above the 1990 level in the 2008–2012 period. We estimate that the tax would reduce emissions in 2010 from around 28% above the 1990 level, on a no policy change basis, to only 22% above the 1990 level.

The analysis of the macro-economic effects suggests that the economic cost of this tax would be quite small. In particular, if the additional revenue were used to fund a reduction in taxes on labour – income tax or social-insurance contributions – it would actually produce a small increase in output and employment in the medium term.

This potential gain is smaller than that estimated in Fitz Gerald and McCoy (1992). This reflects the fact that, with much lower income-tax rates today than in 1992, the distortion to the labour market is greatly reduced and the potential gain from a further tax reduction is reduced. However, as in the earlier study, this study indicates that a carbon tax, combined with cuts in direct taxation, is likely to increase rather than reduce GNP.

This report shows how the potential revenue from a tax (or from auctioning tradable emissions permits) is used is very important in determining whether the measures have a positive or negative impact on the economy. Four possible ways of using the revenue are considered here and the analysis produces a fairly clear ranking on grounds of economic efficiency.

If the revenue from carbon taxes, or the potential revenue from auctioning tradable emissions permits, is used to reduce taxes on labour, the net effects of the change in tax regime could actually prove welfare improving. VAT reductions are marginally less attractive, though they do have some distributional advantages. As with a reduction in taxes on income, by reducing prices, a reduction in VAT will result in a reduction in nominal wage rates. In turn, this will offset the negative consequences of the carbon tax for competitiveness.

Lump-sum payments to households are much less efficient, carrying a significantly higher long-term economic cost. They give no opportunity to reduce tax distortions. Finally, giving away tradable emissions permits free to existing polluters (grandparenting of permits) will be the least efficient way of recycling the revenue, carrying the highest cost in terms of lost GNP. The last two instruments – transfers to households or companies – do not address the loss of competitiveness that the carbon tax entails, leaving the business sector with significantly higher costs in the long run. The transfers to companies also have particularly undesirable distributional consequences, with a significant part of the benefits of the transfers likely to flow abroad. They also involve potentially serious distortions in the cost of capital for participants in the key electricity market.

The results show that the biggest reduction in emissions from energy use would occur in the electricity sector. The next biggest reduction would occur in the industrial sector. The smallest change would occur in transport. This indicates that the lowest cost of abatement in the medium term would be felt by the electricity sector and the next lowest by the industrial sector, as these are the most adaptable sectors.

After 2012, the effects could change and greater adaptation could possibly be efficient for other sectors. Obviously, many of the cheaper options for reducing emissions will have been exploited and the harder issues, such as transport, will remain to be addressed.

Finally, Scott and Eakins (2004) show that families on low incomes are likely to be adversely affected by a carbon tax. As a result, we have assumed that 23% of the revenue from any tax (or auctioning of permits) would be set aside for increased welfare payments or other measures targeted at improving the welfare of low-income families through investment in energy-saving measures.

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