Modelling Climate Change Policy in Ireland: A CGE Approach

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1. Introduction

In May 2002 Ireland ratified the Kyoto Protocol to the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC was agreed at the Earth Summit in 1992. In 1997 the Kyoto Protocol was agreed and set targets to reduce the anthropogenic emissions of gasses that contribute to global warming, the so-called greenhouse gasses (GHGs). Before the Protocol enters into force more countries have to ratify it.

Under the joint fulfilment provisions of the Kyoto Protocol, the EU has agreed to reduce its GHG emissions by eight percent by 2008-2012. As part of the EU burden sharing arrangement Ireland is allowed to increase GHG emissions by up to 13 percent above the levels in the base year which is 1990 for CO_2, CH_4 and N_2O and 1995 for the other three gases (HFCs, PFCs and SF_6). But for the year 2000 emissions were already estimated to be 35.2 percent above the 1990 levels[1]. Thus there is a need for deliberate policy intervention to ensure that Ireland's target can be met.

The Irish government has published a National Climate Change Strategy (NCCS) (DoE, 2000). Without the action set out in this Strategy, it is projected that net annual emissions would increase by 37.3 percent by 2010[2]. Reductions of emissions of 13.1 million tonnes (Mt) CO_2 equivalent (17.7 percent) on this projected figure will be required to meet the national target.

The largest Irish contribution to the greenhouse effect comes from the agricultural sector, mostly in the form of methane from animals. Of all the GHGs, Ireland produces carbon dioxide in the largest quantity. It arises mostly from burning fossil fuels in transport, heating and electricity generation. We will focus on CO_2 emissions from the use and production of energy.

For the energy sector the overall reduction target below business as usual for 2010 is 5.65 Mt CO_2 per annum and the planned policy includes (with CO_2 reduction targets for each as a percentage of the target for the energy sector):

- Fuel switching to gas which is less carbon intensive (73.5%):
    - Measures to cease use of coal for electricity generation by 2008 (60.2%);

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[1] After adjusting for carbon fixation by extended afforestation this figure is reduced to 32.1 percent.

[2] These projections derive from data prepared by Government Departments and ESRI energy and economic development forecasts and are converted into emissions projections by the EPA (DoE, 2000; for details on data sources see p. 86).

    - Substitution for oil by liberalising energy markets (13.3%);
- Expansion of renewable energy (17.7%);
- Maximisation of Combined Heat and Power (CHP) (4.4%);
- Enhanced demand side management (2.7%);
- Efficiencies (0.2%).

Various measures are proposed for the other sectors too. Key measures in the Strategy are

- to gradually introduce taxation from 2002, prioritising taxes aimed at CO_2 emissions. The Minister for Finance indicated in his Budget speech for 2003 that the government is proposing to introduce a carbon tax in 2004.

- to participate in the pilot EU emissions trading scheme and in international emissions trading.

This paper reports on the initial stages of a project to modify an existing CGE model of the Irish economy, IMA*GE*, in order to run climate change policy simulations to identify what are the least cost options. Specifically, the focus of the work is to extend and disaggregate the model in order to be able to analyse options surrounding energy production and consumption.

The objective of the paper is to discuss the most appropriate ways of modelling production and consumption structures in IMA*GE* to include the energy sector as well as the use of various energy inputs by all industries in sufficient detail. In the next section we will summarise the Irish research on the costs of climate change policies and in section 3 we will review a selection of the international literature on this topic. The aspects that are thought to be applicable to the Irish situation will be highlighted and finally we will discuss the constraints which data availability will pose on the modelling work in section 4.

2. Previous Irish Research

The first empirical work assessing the macro-economic effects on the Irish economy of imposing a carbon tax was carried out by Fitz Gerald and McCoy in 1992. The findings were that a tax of 30 euro per tonne of carbon dioxide in 2002 prices[3] would increase tax revenue by almost 2 percent of GNP. The overall implications for the economy depended on how the revenue from the tax was spent. The model they used was the ESRI Medium Term Model (HERMES) supplemented by an energy sub-model, that did not incorporate the following: (1) explicit household consumption of energy, (2) energy as an input in the services sectors and (3) changes in fuels mix due to changes in relative prices (Fitz Gerald and McCoy, 1992).

Conniffe et al. (1997) estimated the cost of abatement through changes in technology, especially in the electricity sector. They found that significant reductions could be

[3] At the time, the proposed EC carbon tax was equivalent to $10 per barrel of oil or IEP7.47 per tonne of CO_2.

achieved by switching to gas firing, but once the possibilities were exhausted, the costs for this sector would rise sharply.

Bergin et al. (2002) use the HERMES macro-economic model with the energy sub-model to forecast energy demand and GHG emissions in the medium term. They find that a carbon tax of 20 euro per tonne of CO_2, increasing with energy prices after the first year, 2003, would cost the Irish economy relatively little, especially if the revenue were used to reduce labour taxes. However, this tax would not lead to the required emission reduction and the additional measures suggested in the NCCS would need to be fully implemented along with an early implementation of the tax. Scott and Eakins (2002) analyse the implications of this tax for the incomes of different household groups, especially households in low-income brackets. If all households receive an average compensation of 247 euro per year, they all gain, on average, from the reform. But within deciles there are gainers and losers. They recommend a more integrated analysis of the tax and welfare system as this would give more refined figures.

3. Energy-CGE Models

Pempetzoglou and Karagianni (2002) review carbon taxation models that have been developed to quantify the impact of the imposition of an energy tax on competitiveness. They categorise the models, inter alia, into four groups: Aggregate and sectoral macro-econometric models (MACRO-A and MACRO-S) and static and dynamic general equilibrium models (SGE and DGE). They conclude that the most suitable types of models for this purpose are the DGE and the MACRO-S models. They emphasise that the values of the parameters for general equilibrium models are calibrated on a single data point, the base year data, while macro-econometric model parameters have to be estimated using time series data. When disaggregating the model by adding an industrial sector or consumer group, the data requirement increases quite a lot. For macro-econometric models the data requirement limits the extent of disaggregation.

Even though the share parameters and the technical coefficients can be estimated from the data in the base year, the elasticities still have to be estimated econometrically for the GE models. However, this still requires a large amount of data for a model to be sufficiently disaggregated to be useful for energy policy analysis.

Internationally, CGE models have become a standard tool for energy policy analysis. Applied general equilibrium (AGE) models have been developed to analyse energy policy and the impacts of such policies on economies, starting with the Hudson-Jorgenson (1974) model. Bergman (1988) carried out a survey of general equilibrium approaches in energy policy modelling. Public concern about the economic impact of changing energy supply conditions has induced the development of energy-economy models based essentially on general equilibrium theory and the neo-classical theory of economic growth. These models can elucidate the adjustment of energy consumption through changes in factor proportions and sectoral output levels resulting from changing energy prices.

Another survey of AGE models for energy studies, most of them applied to climate change policy analysis, has been carried out more recently by Bhattacharyya (1996). In this survey the models are sorted into five groups based on modelling tradition:

1. Multi-sectoral Growth (MSG) following Johansen;
2. Herberger, Scarf, Shoven and Whalley approach;
3. Econometric AGE models following Jorgenson;
4. Structuralist and other social accounting matrix (SAM) based models;
5. Intertemporal optimisation models following Manne.

Many models, e.g., GREEN (OECD, 1992) and ORANI (Dixon et al., 1982). belong to the first group. The G-Cubed model (McKibbin and Wilcoxen, 1993) combines traditions 1 and 4. The main drawback of typical MSG models, especially for energy studies, is the assumption of a representative household (or consumer). The energy sector affects different sections of the population differently.

One example of a model based on the second tradition is that for Italy (Pireddu and Dufournaud, 1996). This paper is interesting because it includes, apart from the standard features (as described in Shoven and Whalley, 1992), a detailed representation of energy consumption by firms and household deciles at the level of four final uses:

- Transport;
- Space heating;
- Energy conversion;
- Other technological uses such as heating for industrial processes and for cooking.

Group 3 replaces the fixed input-output coefficients with econometric models of producer behaviour to generate the demand functions for inputs in each sector. The main difficulty with this is the tremendous data requirements. Also the desirability of econometric parameterisation is debatable[4].

An important structural model is the General Equilibrium Model for Energy-Economy-Environment interactions (GEM-E3), used for European policy issues. It has an unusual optional financial/monetary sub-model that can complement the real side of the model and operates, as an overall closure, following the Keynesian IS-LM methodology (Capros et al., 1997). About this fourth group, Bhattacharyya warns that problems with

[4] The advantages of the econometric estimation of parameters over the calibration approach are stressed by Jorgenson in different works. The main advantage is that the impact of policy changes on patterns of production and consumption are derived from extensive historical experience. Also the parameter values are much less likely to be affected by the peculiarities of the data for a particular time period (Jorgenson and Wilcoxen, 1993). On the other hand they argue that it inevitably captures the extraneous factors like the impact of oil price shocks. Above all, the transition of past experience to the future always remains highly debatable, particularly when long term analyses are carried out (Bhattacharyya, 1996).

interpretation can arise when ad hoc structures are added to the structural models in order to make them more realistic. It becomes difficult to work out what structures in the model lead to the resulting output.

A prime example of group 5 is ETA-MACRO, the global version of which is called Global 2100 (Manne and Richels, 1977). Models of this type are used less often because things like market distortions and fiscal policies cannot be included which greatly limits their applicability.

Bhattacharyya points out nine issues the modeller should keep in mind, of which four are irrelevant for this paper as they concern developing countries and very long term studies. The remaining five are:

A. Results should be interpreted with care: Their robustness depends on parameter values, especially elasticity values, and there is little consensus about different elasticities for energy products in the economic literature;

B. Specification of technology: Existing inefficiencies are implicitly incorporated in the model through parameter estimation. An average function for the energy sector does not do justice to different technologies. Cannot assume that future technology will have same characteristics as in the past;

C. Results depend on model specification[5];

D. Limitations of underlying theories: Most models are based on neo-classical theory. Structuralist models tried to depart from this to incorporate more realism. Even here, problems with interpretation arise when ad hoc structures are added since it is difficult to identify what runs the model;

E. Optimal level of disaggregation depends on what one wants to analyse: A compromise needs to reached based on the objective of the study, constraints on cost, time and other factors.

Some of these studies focus very much on the energy sectors. Three examples can illustrate this approach. Manne and Richels (1977) used a detailed description of energy technologies (energy technology assessment, ETA) that produced electricity and non-electric energy as end-products, while representing the rest of the economy as a single non-energy sector. Factor proportions gradually adjusted to changes in relative prices. Technologies for the future were also included. Even though this is not an AGE model in the strict sense, the solutions from the intertemporal cost minimisation can be interpreted as equilibria in a competitive market (Bhattacharyya, 1996).

The OECD have used the GREEN model to analyse alternative scenarios of international agreements to curb CO_2 emissions. GREEN is a 12-region, 15-sector dynamic model. Twelve of the sectors are energy related, including seven back-stop technologies. Back-stop technologies are substitutes for fossil fuels (oil, natural gas and coal) and electricity generated from such fuels. They are assumed to become commercially available in the

[5] For this reason, Jaforullah (1992) compares three Johansen-type models with production functions of varying flexibility. He finds that it is best to incorporate both inter-factor and inter-fuel substitutions. We will come back to this in Section 4.

course of the simulation period. For every fossil fuel, two back-stop fuels are assumed to exist: one with a higher carbon content and one carbon-free fuel. One representative carbon-free back-stop technology is available to generate electricity, e.g. nuclear fusion, solar or wind power (OECD, 1992).

Edwards and Hutton (2001) analyse the allocation of carbon permits using a stylised static CGE model (based on the Fehr-Rosenberg-Wiegard model described by Ruocco, 1996) in which industry has 12 sectors:

- 9 fuel sectors,
- one energy-intensive industry,
- one other industry
- one aggregate rest sector which includes government and services.

Other studies incorporate energy in a complete picture of the economy. For example, the Australian model ORANI is highly disaggregated (Dixon et al., 1982). Many models are based on this standard example. An energy-related study that uses ORANI with 112 industrial sectors is Hogan and Naughten (1990). Naqvi (1998) used ORANI as a basis for a model for energy policy analysis in Pakistan that has 131 commodities and 102 industries: 15 agricultural, 50 large-scale, 31 small-scale, 4 electricity, one gas, one oil and a rest sector that includes construction and services.

Many models have only one representative household or consumer (the G-Cubed model (McKibbin and Wilcoxen, 1993) is one example), but some distinguish a few different (income) groups (Borgess and Goulder, 1984, use twelve) or even many types (Jorgenson and Wilcoxen, 1993, have 1344 household types in an intertemporal USA model). In the Italian situation Pireddu and Dufournaud (1996) found that breaking the population into equal numbers of households (in their case 2.066 million households per decile) rather than using income classes provided a greater disaggregation of income at the centre of the distribution, which allowed them to analyse more precisely the various taxes aimed at middle income groups.

The level of detail in the production structure also varies greatly among CGE models. For example, Pempetzoglou and Karagianni (forthcoming) use only two levels of CES nesting in the Leontief production function, whereas Sahin (forthcoming) uses 8 levels to describe the combinations of different fuels for various purposes. Electricity production in Naqvi (1998) can be either more flexible (gas turbine & hydro) or less flexible (steam & combined cycle).

Devarajan and Robinson (2002) advise modelers to "be guided by their own version of Occam's Razor: 'Use the simplest model adequate to the task at hand.'"

Generally speaking, two types of models can be distinguished:

- Reduced-form, stylized, often narrowly-focused models that stay close to the underlying analytical model in order to isolate the empirical importance of a theoretically potentially important linkage.

- Applied, structural, usually larger and more complex models that incorporate more institutional and structural detail and encompass a wider spectrum of issues.

Various types of CGE model can be developed. The choice depends on the particular objectives of the study for which the model will be used. Devarajan and Robinson (2002) argue that models destined for use in policy analysis should meet a number of the following criteria:

1. Policy relevance;
2. Transparency;
3. Timeliness;
4. Validation and estimation relevant to the policy issue;
5. Diversity of approaches.

Overall, they recommend structural, or applied, CGE models because "the experience of the past twenty years seems to demonstrate that it is better to have a good structural model capturing the relevant behaviour of economic actors and their links across markets, even if the parameters are imperfectly estimated, because the domain of applicability of such models makes them far more useful for policy analysis" than stylised models.

Efforts have been made to combine the benefits of a detailed model of energy production and a macroeconomic CGE model. This was first tried by Manne (1991) and enhanced by Adams et al. (1991), Jones et al. (1991), McDougall (1993) and ABARE (1996).

More recent work in this area is a study by Li, Huang and Hsu (2000) who integrate the 'bottom-up' "Technology Bundle" approach into the 'top-down' CGE framework. In their resulting model there are ten different technologies to generate electricity:

1. Hydro;
2. Stream turbine-oil;
3. Stream turbine-coal;
4. Stream turbine-gas;
5. Combined cycle-oil;
6. Combined cycle-gas;
7. Gas turbine-oil;
8. Gas turbine-gas;
9. Diesel;
10. Nuclear.

The electricity industry is able to substitute between technologies in response to changes in relative costs. The output of the electricity sector is an aggregate of the electricity generated from each of these technologies. The "Technology Bundle" approach, proposed in ORANI-E and MEGABARE (GTEM), ensures that the model can only choose technically feasible combinations of inputs as a solution. This makes the model more realistic. The extensive interaction with other sectors of the economy is retained from the ‘top-down’ model TAIGEM-D, the dynamic descendant of the TAIGEM MARKAL model which was derived from ORANI.

Kemfert (1998) estimates elasticities of substitution between the factors energy, capital and labour. Based on the data, they prefer the model where a composite of energy and capital (KE) trades off against labour (L) for the entire German industry. This finding is used in the CGE model by Kemfert and Welsch (2000). The same KE-L structure can be found in models by Galinis and Van Leeuwen (2000) and Wendner (2001).

4. Model Structure for Climate Change Policy Analysis in Ireland

Decisions on how to adapt IMA*GE* for climate change policy analysis can be guided by:

- The issues (A-E) to keep in mind as pointed out by Bhattacharyya (1996);
- The five criteria for policy models according to Devarajan and Robinson (2002).

We will draw conclusions for this paper by discussing each of these issues/criteria as listed in section 3 in the context of the model for Ireland.

4.1 Issues

A. Estimation of elasticities will be a problem whatever format is chosen. We can only try to limit the number of parameters that need to be estimated by reducing the model to the minimum necessary complexity. This approach is generally recommended for policy modelling (Devarajan and Robinson, 2002).

B. As regards specifying the technology, the ‘Technology Bundle’ approach seems to be the solution. Technologies that are not yet economically viable should be included in the model because they may well become viable in the future and prove to be an important substitute to conventional technologies. In Ireland nuclear power generation is not a realistic or viable option. Hydro, wind, tidal, solar, biomass, landfill gas and combined heat and power as well as the usual fossil fuel fired electricity generation are useful technologies/energy sources to include in the model. Data on the costs structures of the new technologies will have to be gathered from the industries rather than from the literature. The problem of price elasticities can be reduced by assuming that these new sources will only be applied to electricity generation and possibly transport. That way there is no need to find out, for example, how many households would switch to solar energy for their heating needs if the price comes down. Even though this may seem a huge omission, in reality many households are unlikely to make such dramatic changes. The new technologies would have a better chance in the household sector if investment in them were subsidised (or at least exempt from tax) and new houses were required to be built with the new technologies. We will also look into the possibility of introducing a specification of energy consumption by firms and household deciles similar to the four final uses as adopted by Pireddu and Dufournaud (1996). Considering data limitations, it may be necessary to reduce the number of final uses for our energy model.

C. As stated above, the results of the model will be sensitive to different model specifications. Based on the comparison of the effects of an identical oil price change simulated by three CGE models with different levels of flexibility in the production specification regarding substitution between fuels and factors, Jaforullah (1992) concludes that energy-CGE models can produce biased results if inter-fuel and inter-factor substitution are not incorporated. He recommends using a production function that allows for substitution or complementarity between various factors and also between a range of inputs including various fuels. He concedes however, that severe data problems may force the model builder to use a more simple model. It may be worthwhile to use a few different specifications in the adapted IMA*GE* model to check how sensitive the results are. If the results are more or less the same, the most straightforward functions will be applied, again to reduce complexity and limit the need for estimation of elasticities.

D. As stated, models are limited by the theories on which they are based. Initially, the existing model, IMA*GE*, was a standard static neo-classical CGE model, but it has been improved to include imperfect competition and endogenous labour supply. This feature is envisaged to be retained when the model is adapted for climate change policy analysis. Any further such improvements will also be adopted in the energy version as they are added to the original model. If the interpretation becomes too complicated we will have to reduce the model back to being more simple and less realistic. There is no point in using a model when the output cannot be interpreted.

E. The optimal level of disaggregation depends on the objectives of the study. The data and parameters for 34 Irish sectors are available from the IMA*GE* database SAM (O'Toole and Matthews, 2002). In IMA*GE* there are presently 11 agri-food sectors because it was originally built for agricultural policy analysis. In the energy version we will need to disaggregate energy sectors. Some of the data needed for those can be obtained from the Economic and Social Research Institute (ESRI), the Central Statistics Office (CSO) and the Department of the Environment and Local Government. For the analysis of the impact on income distribution we need to distinguish a number of representative households. The results of the Household Budget Survey "make it possible to describe household purchases of fuels and associated expenditure in considerable detail" and with the accompanying income data, households can be categorised into deciles of gross household income (Scott and Eakins, 2002). Parameters will be more difficult to estimate but a start has been made at the ESRI: Long-run price and income elasticities for electricity and non-electrical energy have been estimated for three sectors, i.e., households, services and industry (Bergin et al, 2002). To reduce the number of parameters in the energy model we have to aggregate some of the agri-food sectors.

4.2 Criteria

1. Policy relevance: The energy version of the Irish model will be very different from the original model because it will focus on the energy sector, disaggregate the households and reduce the emphasis on agriculture (as mentioned above under E). However agriculture is still a large sector in the Irish economy and it is important to model the feedback correctly.

2. Transparency: Keeping the model as simple as possible is already needed for the reasons mentioned above and will also help to keep it understandable.

3. Timeliness will be achieved by using the latest input-output data available. We will create a new database based on the new I/O table which will be available soon from the CSO and the 2003 IMA*GE* database that was created from the 1998 database using a method that was especially developed to update the data.

4. Validation and estimation relevant to the policy issue: The parameters, where available from the ESRI, are estimated in the context of climate change policy analysis. When we get to the validation stage we will keep that objective in mind when selecting the topic for the sensitivity analysis.

5. Diversity of approaches[6]: In Ireland, research has been carried out using a macro-econometric model as mentioned in section 2. Applying a CGE model to the analysis increases the diversity of approaches. The results will be compared once the model is finalised. The scenarios will be chosen to match scenarios run with the HERMES model to facilitate this comparison.

[6] Bach et al. (2002) use two different models:

- A multi-sector econometric input-output model with 58 sectors, PANTA RHEI;
- A dynamic two-region empirical CGE model with emphasis on energy markets, LEAN.

The macro-economic results are linked with a micro-simulation model for the household sector to establish income distribution effects. Overall results are the same. But sectoral outcomes are ambiguous. PANTA RHEI predicts less structural change than LEAN due to the different modelling strategies. LEAN translates cost changes directly into price changes, but with PANTA RHEI higher costs in energy-intensive sectors can be absorbed by lower profits as well as higher prices, so that these sectors can limit their output decline in spite of increasing costs.

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