APPENDIX 1: THE ESRI MEDIUM-TERM ECONOMIC MODEL[1]

A1.1 Introduction

Unbeknownst to most people they carry round with them in their head a model of the economy. Most non-economists have a clear understanding of some key economic relationships: higher income leads to higher consumption; falling output can jeopardize jobs. What a formal macro-economic model does is to make explicit in mathematical language a range of assumptions about how key relationships work – an "informal model". These key relationships, when formulated as equations, can then be tested statistically. When put together, the different key economic relationships then form a model of how the economy works.

Such macro-economic models provide an important tool in expanding our understanding of how the economy works. The key relationships in the model can interact in unexpected ways, helping us understand the complexity that is a real economy. They allow us to test our prejudices and confirm or often reject them. They also help in quantifying how important different factors may be in determining the course of the macro-economy. Finally, they provide a framework for testing new ideas, ensuring that the wide range of factors affecting economic outcomes is handled within a consistent framework.

Most of the economic forecasting reported regularly in the media is of the short-term variety. Attention is focused on the demand-side of the economy, and on the incomes generated by expenditures on consumption, investment, trade, etc. Production capacity is regarded as fixed, the short-term issue being the rate of capacity utilization. Attention to public policy tends to focus on the immediately preceding and/or anticipated budget. This type of forecasting depends on a few key relationships and the "informal model" or simple mathematical models are most suitable for this type of work.

When one moves further into the future, the situation becomes much more complicated. Investment activities can change the productive capacity of the economy; some sectors may decline, others may grow; policy changes which have only minor short-term implications can have major long-term consequences. In short, everything becomes mutually interdependent, and the ultimate consequences of policy or other shocks become difficult to disentangle using judgement or *ad hoc* methods. Under these circumstances a formal macro-economic model is essential to ensure coherence and internal consistency in forecasts. However, the forecasts themselves are the result of economists working with models, not independent products of the models themselves. The use of a formal model is absolutely essential when it comes

[1] An earlier version of this chapter appeared as an article by J. Bradley and J. Fitz Gerald (1991).

to simulating the effects of alternative policies or shocks that may affect the economy in the future.

Ever since data on the economy became widely available (an important by-product of the development of Keynesian macroeconomics in the 1930s and 1940s), economists have attempted to test their theories by constructing formal quantitative models (i.e., models that tell you the magnitude as well as the direction of any given result). The early models displayed their Keynesian origins in their focus on the demand side of the economy with little attention paid to the supply side.

However, as the world changed in ways that were not anticipated by Keynesian economists, ideas and theories of how the economy functioned also changed, albeit with a delay. For example, during the 1970s the world economy was hit by a series of massive supply-side shocks (energy shortages, oil and other commodity price rises), which opened up serious weaknesses in the demand-side underpinnings of most operational economic models then being used. For a time modelling went out of fashion, since it provided a poor guideline on how to grapple with a supply-side recession (referred to popularly as *stagflation*; low growth combined with high inflation).

Underpinning all aspects of the ESRI medium-term model are the insights derived from neo-classical economics – prices matter. Firms and households both respond to changes in relative prices through changing their consumption patterns (households) or changing their level of output and demand for inputs (firms). Higher relative prices mean less consumption of a good or service by households. Higher prices for inputs (e.g. labour, capital, energy) relative to the prices firms can charge also adversely affects firms' output. In turn, changes in the relative cost of inputs may change the optimal mix of inputs used by firms. Changes in the cost of production in one region or country can also affect the location of production.

A central feature of this approach is the estimation in a consistent manner of a model of how firms in different sectors are likely to respond to changes in the prices of their inputs and the price of their output. In the 1970s the big changes in relative prices caused by the oil price shocks had substantial implications for the profitability of firms and their long-term output levels. Over the following decade this drove extensive research by economists into the economics of production.

The late 1970s and the 1980s saw the emergence of conflicting viewpoints and theories of how economies work. Three main schools emerged:

(a) *The New Classical School*: These economists hold that, contrary to the old Keynesian assumptions, markets do clear very quickly (i.e. prices and wages adjust to ensure that supply equals demand in each market) and that people form their expectations rationally, i.e., using all available information. They provide little or no role for public policy in boosting output or reducing unemployment, even in the short term.
(b) *The Monetarist School*: These economists believe that while the economy has a natural tendency to move towards equilibrium, this can take a long time since prices and wages only adjust very slowly. They believe that only inflation results from government boosts to demand, and that no attempt should be made to "fine-tune" the economy using discretionary policy actions. Rather, policy makers ought to adhere to stable and robust policy rules that are announced well in advance.
(c) *The New Keynesian School*: This is the lineal descendant of the original Keynesian economics of price rigidity and non-clearing markets, updated with a more sophisticated modelling of expectations, wage-price rigidity and supply-side responses. It holds that although markets may clear in the very long run, there is at least some role for public counter-cyclical policy.

It is from the latter New Keynesian school that the ESRI medium-term model draws its inspiration, building on the earlier Keynesian model developed in the Central Bank and the Department of Finance in the 1970s, (see Bradley *et al.*, 1978 and Fitz Gerald and Keegan, 1981) and incorporating much new research on the production side of the economy. This new model of the Irish economy was originally part of an EU-wide system of macroeconomic models – *HERMES* – that were specifically designed to deal with supply-side issues. The *HERMES* model structure was designed to answer problems arising from the oil price shocks of the 1970s, problems that earlier models could not hope to tackle. The Irish version of *HERMES* was modified to deal with the special circumstances of the Irish economy. It was described in detail in Bradley *et al.*, 1993. This version of the *HERMES* model was used in the *Medium-Term Reviews*, covering the periods 1987-92 and 1989-94.

In order to model the effects of the EU Structural Funds and the effects of the completion of the Single Market the model was developed further in 1990-91. The *HERMES* model took on its present form as a result of this research, with significant further elaboration of the supply side to deal with eleven sectors of the economy and the complexity of the processes driving these eleven sectors.

This chapter aims to provide a non-technical introduction to the present revised and extended version of the ESRI medium-term model. In Section A1.2 we give an overview of the key mechanisms in the model, and follow in sections A1.3 – A1.7 with more detailed descriptions of the main subsectors: manufacturing, services, and the public sector, and of the labour supply and the expenditure (or absorption) sides of the model. Section A1.8 provides a description of the energy sub-model, which is embedded within the medium-term model. Throughout the 1990s there was a monetary – exchange rates section of the model, but the advent of monetary union means this no longer plays a role. We conclude with an impression of how we think the model provides a guide to the future evolution of the economy and how it helps present starkly some central policy dilemmas.

A1.2 An Overview of the Model

Economists have three different ways of looking at the behaviour of the economy. They examine what is produced (for example, output from the industrial sector); what is spent (e.g., private consumption, investment, etc.); and the incomes earned by the factors of production (e.g., the industrial wage bill, profits, etc.).

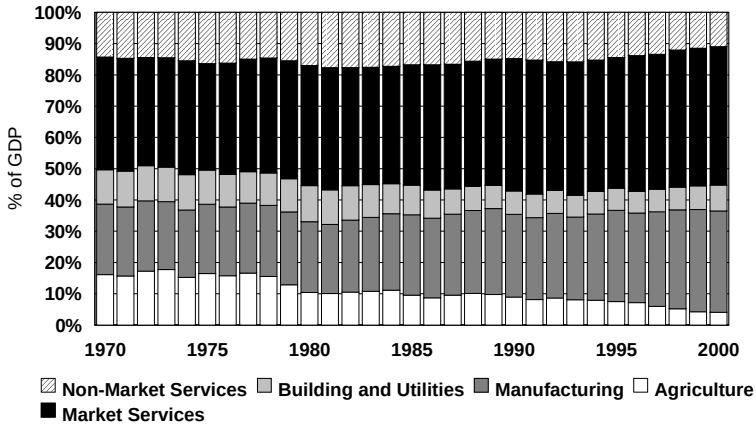
Each approach (output, expenditure and income), should lead to an identical measure of gross domestic product (GDP), being the conventional aggregate measure of activity in the entire economy. Short-term forecasts (such as those published regularly in the ESRI's *Quarterly Economic Commentary*) focus on expenditure-income relations. The ESRI *Medium-Term Review* adopts a longer time horizon of five or more years. With this medium-term orientation in mind, the ESRI economic model of the Irish economy focuses initially on the output (or production) relationships, and examines the downstream expenditure and income consequences. The key mechanisms within the model are shown in the box.

(1) The exposed sector is driven by world demand, elements of domestic demand, and cost competitiveness.
(2) The sheltered market sector (services and building) is driven by domestic demand.
(3) The public sector is policy-driven, with treatment of borrowing and debt accumulation.
(4) Wages are determined in a bargaining model, and influenced by the factors that affect the supply and demand for labour – e.g. prices, taxes, and unemployment.
(5) The labour market is open and influenced by conditions in the UK labour market.

An initial distinction can be made between those sectors of the economy that are exposed to the competitive world trading environment (the internationally traded sector – henceforth referred to more simply as the *traded* sector) and those sectors that are sheltered from direct exposure to international competitive trade (referred to more simply as the *non-traded* sector). Broadly speaking, the traded sectors consist of manufacturing, most of agriculture, and an element of market services (e.g., financial services, software, tourism, etc). The non-traded sectors comprise the rest (i.e., utilities, building services, most of market services and all public or non-market services). The relative sizes of these sectors, in terms of added value, are shown in Figure A1.1.

Given the extreme openness of the Irish economy (the total of imports and exports is expected to be 230 per cent of GNP in 2003), we give primacy to the traded sector as the main engine of sustainable growth in the Irish economy. In the case of manufacturing, there are two key determinants of growth: the state of world demand[2] and the level of Irish cost competitiveness relative to its trading partners.[3] Hence, the two external forces driving the Irish manufacturing sector's output are the rate of world growth (which is more-or-less-transmitted one-for-one to Ireland) and the level of world cost competitiveness, which Ireland must at least match in order to grow as fast as the world economy. Any gain in competitiveness results in an increase in market share and growth faster than the world economy. Any loss of competitiveness reverses this process.

Figure A1.1: Sectoral Share of Gross Domestic Product



[2] We use the term "world" somewhat loosely in this Appendix, where a more correct usage would consist of a trade-weighted measure of activity in a range of countries in Ireland's trading sphere.

[3] In some subsectors, we shall see that the state of domestic demand also plays a role, but one which is subsidiary to world demand.

Obviously the decisions on the optimal level of output in Ireland are implemented through investment decisions by individual firms – either investing to build new plant or decisions to close existing plant. In the case of the high technology sector the bulk of the new investment comes from foreign firms and takes the form of foreign direct investment (FDI).[4] Thus the level of foreign direct investment into Ireland is seen as ultimately a function of the world demand for the relevant product and the competitiveness of the Irish economy as a location from which to supply that world market.

Given the level of output in manufacturing, the manner in which it is produced is then determined in the model. Firstly, arising as a consequence of its exposure to world competitive forces, Irish manufacturing output prices are determined primarily in the world market place and cannot easily be altered to respond to Irish cost conditions. In other words, Irish firms trading internationally tend to be "price takers". The appropriate mix of labour, capital and material inputs depends on their relative prices. For example, if wage inflation outstrips rises in the cost of capital, there is some scope for substituting capital for labour in the medium-term production process. In addition to relative price terms, there is also a systematic trend in the use of some factor inputs due to "technical progress". For example, in manufacturing there is a tendency towards "labour saving technical progress", i.e., less labour is needed each year to produce the same level of real output. The determinants of technical progress are a complex mixture of catch-up factors, human capital, physical infrastructure, business efficiency, and policies targeted at innovative firms.

Developing on the above outline, the ESRI model contains equations describing the determination of manufacturing output and factor inputs, in terms of external forces (world output and world competitiveness) and domestic forces (mainly Irish wage costs, with some role for domestic demand). Since output prices and the prices of material inputs and capital are largely determined externally, attention is focused on the determination of wage rates.

Wage rates are modelled as the outcome of bargaining between trades unions and employers, with the frequent intervention of the government through the tax and welfare systems. The factors driving employers in bargaining include the price they can get for their product or service, their competitiveness in their key markets, the taxes they pay, and the productivity of the individual firm. The price that employers obtain for their product clearly influences the price at which they can profitably purchase factor inputs, like labour. The price they are prepared to pay for labour in Ireland is also affected by the price they would have to pay for labour elsewhere.

Employees are assumed to bargain in terms of their real after tax wage. They bargain with employers and, when the rate of pay is agreed, employers are then assumed to choose their optimal employment level. Their take home pay is clearly affected by consumer prices and the taxes that they pay on their earnings. As discussed later, migration is itself directly affected by labour market conditions in Ireland relative to other countries. This affects the wage bargaining process, directly through changing domestic labour supply, and indirectly through affecting the expectations of Irish employees.

In bargaining, employees are also concerned about what they could get by working for other employers, or what they would receive if they lost their job altogether. Thus the unemployment rate (and possibly rates of benefit) can also play a significant role in determining employees' expectations and their bargaining behaviour. Economists call the effect of unemployment on wages the "Phillips curve"; it basically states that the tighter the labour

[4] For the traditional manufacturing sector and the food processing sector a higher proportion of the total investment is accounted for by domestic firms.

market, the higher will be wage settlements, and vice versa. However, in the case of Ireland, because of the integration of the labour market into the broader EU labour market through migration, the unemployment rate may not be a good indicator of the labour market circumstances that individual workers face. They may not remain unemployed in Ireland but may prefer to emigrate. The bargaining power of individual workers will also be affected by the degree of unionisation in the Irish market. Finally, the productivity effect comes as workers try to participate in the benefits of real growth – they will attempt to bargain to maintain their share of value added.

In such models, wages are determined by a range of explanatory variables including: output prices, the "wedge" driven by taxes between the wage denominated in the employer's (output) price and the take home consumption wage enjoyed by workers; the rate of unemployment; and labour productivity; the returns to working outside Ireland, the cost of employing labour outside Ireland, and unionisation.

Turning now to the non-traded sector, consider the behaviour of the large market services sector. Leaving aside tourism and other traded services – a growing fraction of the total – output in market services is driven mainly by domestic demand. So, for example, private consumption will contain a certain element of services sector output (transport and communication, recreation, professional services, etc.), and any change in consumption will impact on the demand for services sector output accordingly.

Services sector output is assumed to be produced by firms in a way that minimizes the costs of production. Hence the mix of capital and labour inputs is sensitive to the relative prices of the inputs, as in manufacturing. However, given its insulation from world competition, prices in the services sector tend to be determined as a mark-up on input costs. Hence, if these services are required as inputs into manufacturing, a loss in industrial competitiveness can result if the price of Irish services rise excessively.

It is the balance between the traded and the non-traded sectors that makes the Irish economy (and, consequently its modelling) interesting and more complex than the highly stylised "small open economy" model that is developed in economics' textbooks. Indeed, the export-oriented development of the Irish manufacturing sector through multinational foreign direct investment makes the Irish economy quite unique among the EU peripheral members.

A1.3 The Manufacturing Sector

The 1980s version of the ESRI model contained an aggregate industrial sector, comprising manufacturing, utilities and building. Experience with that model pointed to the need to disaggregate the sector into five subsectors: a separate treatment of utilities and of building, and a three-way breakdown of manufacturing.

Examination of manufacturing illustrated that there were three quite separate components in terms of how the subsectors functioned. First, a high-technology sector could be identified, which was largely foreign owned, almost 100 per cent export oriented, was capital and R&D intensive, and which had a high propensity to repatriate its profits out of Ireland. Second, the food processing sector had a unique dependence on domestic agricultural production (mainly of cattle and milk), and fell under the influence of the EC Common Agriculture Policy (CAP), with its price and quota rules. Finally, the traditional manufacturing sector covering a diverse area of drink, textiles, clothing, wood, paper, publishing, etc., was mainly in domestic ownership, tended to be more labour intensive than the other sectors, and was less export oriented (but still trades over 60 per cent of its output).

The three subsectors of manufacturing differ in terms of their driving forces. The high-technology sector is driven by world demand (with no

domestic demand influence) and international competitiveness. Output in the food processing sector is constrained by Irish agricultural production within the CAP. In the third – traditional – sector, both world and domestic demand play a role, together with international competitiveness.

The factor inputs were modelled in a way that recognised that the capital stock could only be varied slowly over time, whereas the other inputs (labour, energy and other materials) could be varied more rapidly in response to changes in relative prices. A full technical description of the findings concerning the underlying technologies of the three sectors is available, see Bradley, Fitz Gerald and Kearney (1993).

Briefly, it was found that the possibilities of substituting the different factor inputs (labour, capital, materials) were more restricted than might apply in a larger, less open, economy such as the USA, Germany or the UK. In the case of the high-technology sector, the low possibilities of factor substitution within Ireland are in stark contrast to the greater possibilities of relocating the entire production process out of Ireland, if international competitiveness is lost.

A1.4 The Market Services Sector

The first version of the ESRI model contained an aggregate market services sector based on the very limited data available at the time from the CSO. The very heterogeneous nature of the sector made the construction of an aggregate model very difficult to justify, and the *ad hoc* model lacked any firm foundation in economic theory. The advent of the Single European Market in 1992 made it imperative to understand the behaviour of the market services sector, since this sector was likely to bear some of the burdens of rationalisation within the single European market (e.g., rationalisation of distribution and opening up of financial markets).

In the present version of the ESRI model market services are split three-ways: distribution (wholesale and retail), transport and communications, and other (professional, financial, personal) services. In each case, the scale of output is determined in the model by a suitably weighted measure of final demand (e.g., the weights determining, say, distribution output reflect the distribution content of consumption, etc.).

The special nature of the transport and communications sector is recognised in the model, where the capital stock varies very slowly over time and was subject to public sector influences over much of the last thirty years (e.g., the massive investment in telecommunications during the first half of the 1980s). However, in the other two sectors the mix of capital and labour is sensitive to factor prices. In addition, "technical progress" was found to be labour using in other services (i.e., over time output becomes more labour intensive in other services). A full technical description of the market services sector is available in Bradley, Fitz Gerald and Kearney (1991).

A1.5 The Supply of Labour

The demand for labour is determined in the production block of the model, as a derived demand, and is influenced by the scale of output, prices (including the wage rate), and trend terms capturing technical progress. The supply of labour consists of a series of relationships determining population of working age, participation in full-time education, participation in the labour force, and migration.

Underlying the medium-term model specification is a much more detailed demographic model developed by the ESRI. This model is used to estimate the likely natural increase in the underlying population of working age. Because of the different pattern of labour market participation for males and females, the supplies of female and male labour are modelled separately. The model is driven by the educational attainment of the population. The final educational of each cohort is assumed to be determined at age 20. Then the

numbers with each of the four levels of education in each cohort are determined by ageing, by deaths and by migration. In turn, female participation rates are determined by the educational attainment of the cohort. This labour force participation ratio is determined by such factors as the probability of obtaining work; the returns to employment; and slowly changing sociological factors.

The final chain in the determination of labour supply is migration. Net outwards migration is determined by the relative attractiveness of alternative labour markets, proxied by the United Kingdom. For example, if the returns from working in Ireland improve because the Irish rate of unemployment falls relative to the UK there will be a tendency for inflows of migrants to start up or accelerate. In addition, if the returns to working in Ireland improve relative to the UK, measured in terms of relative real after tax earnings, a further tendency to immigration will be created.

The migration mechanism is one of the more crucial relationships in the model but the changing character of migration – the growing numbers of non-Irish citizens in the migration flows – means that past behaviour may be a less reliable guide to future population movements than it was over the last decade. In addition, issues, such as the cost of housing and relative congestion levels, may also affect choices on migration, even though they are not currently captured in the model.

To ignore the possibility of migration (i.e., to assume that the Irish labour market is "closed") would be to commit a serious error, leading to an overestimate of the forces operating between higher unemployment and wages in the Phillips curve (see above), driving down wages and pricing labour back into jobs. However, too high a model sensitivity of migration outflows to any deterioration in the Irish labour market leads to a serious underestimate of the equilibrating powers of higher unemployment on wages. On balance, we feel that the long-run migration relation is adequately captured in the model, but the timing of short-run responses may not be handled satisfactorily by our approach. However, as the increasing integration of the Irish and the broader EU labour markets continues, there may be a change in the sensitivity of migration movements to labour market conditions over the coming decade.

A1.6 The Public Sector

Although we could attempt to explain public sector behaviour in terms of the implicit or explicit objectives that a society may set itself, most conventional economy-wide models take the key decisions of the public sector as determined by forces not explained within the model. So, for example, the numbers employed in the public sector, tax rates and rates of income support are taken as given. Of course, one may manipulate such policy instruments in order to achieve different outturns, but the policy settings (public employment, tax rates, etc.), are not on "auto-pilot", and can be changed arbitrarily by the policy maker, within the bounds of political and financial feasibility.

The output measure of public sector activity is essentially determined by public employment inputs, and appears in the model on the expenditure side of the national accounts as public consumption. Financing public consumption represents ultimately a burden on the rest of the economy, a burden that can only be delayed if resort is made to debt rather than tax financing.

A wider measure of the size of the public sector in the economy consists of total public expenditure, obtained by adding public consumption, subsidies, current and capital transfers (such as unemployment benefits and IDA grants to industry), national debt interest payments and public investment expenditures (such as housing, roads, etc.). These additional expenditure items are also included in the ESRI model as the product of

some notional "rate" applied to a notional "base" (e.g., expenditure on unemployment income support transfers is determined as the product of an average rate of income support – a policy instrument – by the numbers unemployed and entitled to benefit (determined elsewhere in the model). The main tax revenues are similarly determined as the product of an average tax "rate" by a notional tax "base" (e.g., VAT receipts are determined as the product of an average VAT rate – a policy instrument – by the VAT base, being essentially the value of consumption expenditures.

The exchequer surplus is the difference between tax and other revenue and current expenditure. While theoretically any level of public expenditure could be financed by raising taxes and keeping the exchequer surplus/ borrowing requirement (EBR) roughly in balance, in fact resort was made both to tax financing and to borrowing during the 1970s and 1980s. During the 1980s, financing the burgeoning EBR required the state to borrow both domestically and abroad, and to accumulate a large national debt. Domestic borrowing is set in the model as a proportion of domestic savings, and the residual deficit is financed by foreign borrowing. A useful measure of the debt-servicing capacity of a nation is the accumulated national debt as a proportion of GNP (the "debt/GNP" ratio), a variable also determined within the model.

Finally, there are two options included in the public sector that facilitate the use of the model to explore the possible effects of changes in public policy and different scenarios involving variations in the underlying macro-economic assumptions.

The rates of taxation and government expenditure are suitably indexed so that changes in the assumptions affecting the rate of inflation can directly affect government expenditure and revenue.

There is an option to impose an unchanging government borrowing requirement in the face of the different scenarios. This option is similar to one used in the IMF *MULTIMOD* world model, where it is also used to explore alternative macro-economic scenarios. This option is implemented by making the rate of direct taxation change to ensure that the borrowing requirement remains at a preordained level, in spite of the changing macroeconomic environment.[5]

A gap in the model structure is the absence of any mechanism to prevent the balance of payments deficit or surplus growing monotonically in the face of shocks. Ideally there should be a wealth effect, which would ensure long-run equilibrium. For example, if the model showed an ever-increasing surplus, the build up of foreign assets, which this would represent, should ultimately affect domestic consumption through its effect on wealth. In practice, this issue must be dealt with directly by users of the model outside of the model structure.

A1.7 National Expenditure

The expenditure side of the national accounts consists of private and public consumption and investment, stock changes, exports and imports. Certain key elements of expenditure in the ESRI model should be emphasised.

The quest for a stable and robust model of private consumption behaviour has taxed, and continues to tax, the brains of economic modellers both in Ireland and abroad. Over the past decade our approach has been to use the very simplest model where consumers are assumed to be liquidity constrained. This implies that consumption is determined by current personal

[5] Alternatively, one of the components of government expenditure, such as public employment, can be assumed to vary to ensure that the borrowing requirement remains unchanged compared to the predetermined level.

disposable income, excluding any wealth effects. However, the current version of the model also includes a housing wealth effect in the consumption function, which proved significant when the data for the 1990s were included in estimation. This implies that when real housing wealth rises, for example because real house prices rise, there is a positive effect on consumption. International evidence also supports the existence of a "wealth effect", see for example Case, Quigley and Schiller (2001).

Private investment is determined on the supply side of the model, described above, as a derived factor demand into the production process.[6] So, investment is determined initially by sector, and the aggregate sectoral investment is split between its two main components: machinery and equipment, and building and construction. The public elements of consumption and investment are used as policy instruments in the model. The exception is investment in housing which uses a model derived from work by Murphy and Brereton, 2001. In the model demographic factors, income, and the real cost of housing (including interest rates) all affect housing demand. Housing supply is affected by the profitability of house building, proxied by the price of houses relative to the cost of producing them. An overview of the housing section of the ESRI macro-model is given in Duffy (2002).

Industrial exports are determined in a supply function in terms of sectoral manufacturing output, where the marginal propensities to export the output of each sector are estimated, and corrected by a time-trend, permitting the export share of output to rise over time. Because of the importance of foreign direct investment in Ireland, we model separately profit repatriations by foreign multinationals. The level of repatriations by these firms is a function of their profitability operating in the Irish economy.

Finally, there is no conventional demand for imports equation in our model. Rather, we determine all the separate sectoral components of output, and all the elements of final demand. Imports are determined as a "residual", i.e., as the difference between output and final demand.

If Ireland faced a binding balance of payments constraint (like many third world countries), the ability to import would be constrained by the ability to finance the balance of payments deficit. In practice our approach simply imposes consistency between domestic supply (determined in the production block) and domestic demand (determined in the absorption block).

A1.8 The Energy Model

The energy sub-model is used to produce consistent forecasts of energy demand and of greenhouse gas emissions from energy. The modelling framework makes it possible to simulate the effects of alternative policies on reducing greenhouse gas emissions, see Bergin, Fitz Gerald and Kearney, 2002.

The energy model is built up as four separate, though interrelated, blocks.[7] 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.

[6] Private housing investment is determined separately as a function of real disposable income, and the real cost of borrowing.

[7] A complete description of the model is available in ESRI Working Paper 146.

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 carbon dioxide 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 medium-term 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.

With the introduction of the new energy model the specification of the utilities sector, which is the domestic producer of energy, has been changed. It is through the equations in this sector that the engineering data on the consumption and production of energy measured in tonnes of oil equivalent (TOEs) from the energy model are converted into economic variables determining output, inputs and prices in the utilities sector. Furthermore in the determination of household consumption, the consumption of energy has been separated from non-energy consumption, and a personal consumption deflator for energy is derived.

A1.9 The Model as a Guide to the Future

Economic models are used in two different but related situations: forecasting and policy analysis. If one requires simply to forecast aggregate Irish GNP forward a year or two, a simple approach based on extrapolating recent past GNP trends, adjusted by a study of likely future world trends, and applied with a dash of common sense will probably out-guess any large structural economic model! However, if a series of detailed sectoral forecasts, based on a range of different world scenarios and domestic policy stances, is required, the simple isolated time-series approach becomes less relevant.

In such a situation, a large-scale structural model has its own set of problems. For example, the so-called "Lucas critique" (after the Nobel prize-winning US economist of the New Classical school, Robert Lucas) holds that model-based policy analysis is invalid since the model's structural parameters (the numbers obtained from statistical analysis of past data) cannot be assumed to remain unchanged in the face of policy regime shifts. However, it is generally accepted that the force of the Lucas critique is greatest in the case of "reduced form" models, i.e., small-scale models whose equations represent a mixture of behavioural, policy reaction and *ad hoc* elements. Nevertheless, even for structural models, care must be taken to ensure that one does not stray into configurations of the economy which are very different to those which characterised the years used for model calibration.

Another aspect of modelling concerns the formation of expectations. Most conventional models (including the ESRI model) use adaptive or extrapolative expectations mechanisms, which basically say that future performance of a particular variable is affected only by its past. A more recent development uses "rational" expectations mechanisms, which assume that people form their view of the future by taking account of all available information, including available economic model forecasts. This approach is particularly important when modelling the behaviour of interest rates and

exchange rates. However, with membership of monetary union, this section of the model is now replaced by the NiGEM world model.[8] The NiGEM model builds in such forward-looking behavior. In other areas it is possible that "rational expectations" could play a significant role (for example in the housing market) and the incorporation of such forward-looking behaviour into the model is on the future research agenda for the ESRI.

The model can be used to develop medium-term forecasts, conditional on judgemental assumptions concerning the world economy and domestic policy. It provides an essential accounting and economic framework within which to formulate and evaluate forecasts. Over the last decade the most frequent application of the model has been to carry out a form of policy and scenario analysis. For example, the model has been used to examine the likely implications for Ireland of EMU, of a minimum wage, of benchmarking, the effects of investment funded by the EU, and to help develop the priorities for future public investment. In addition, it has been used extensively to examine scenarios involving alternative assumptions about the external environment facing the economy. Examples of this latter kind of analysis are included in Chapter 4 of this *Review*. Ideally, such scenarios should not differ massively from the historical inputs. In practice one pushes the model to its limits and beyond, and must adjust one's evaluation of the validity of the results accordingly.

[8] The UK National Institute for Economic and Social Research (NIESR) *Global Econometric Model* (NiGEM). We are very grateful to Ray Barrell and Ian Hurst of NIESR for their assistance in using the NiGEM model.