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ISSUES IN IRISH ENERGY POLICY

Edited by
John Fitz Gerald and Daniel McCoy

ECONOMIC & SOCIAL RESEARCH INSTITUTE

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Chapter 1

INTRODUCTION

John Fitz Gerald and Daniel McCoy

In the past public interest in energy policy has fluctuated with movements in energy prices; when prices were exceptionally high interest peaked. Since 1986, when energy prices fell precipitately, energy policy has attracted much less public attention or scrutiny both internationally and in Ireland. However, the cost of energy to the economy still remains substantial to both the household and the productive sector. As an important input to industry, movements in domestic energy prices can significantly affect Irish competitiveness. The Report of the Industrial Policy Review Group (1992), among others, has highlighted this issue. In addition, technical change, the growing attention to the environmental consequences of burning fossil fuels, and developments in the EC are posing new challenges for policy requiring a re-examination of our traditional outlook.

This Policy Research Paper examines the changing context for energy policy in Ireland, in particular the implications of developments at an EC[1] level for how we organise the production and distribution of energy. It publishes in revised form the papers presented at a conference organised by the Energy Policy Research Centre in the Economic and Social Research Institute in March 1993.

EC Policy

At a European level there has been an increase in the pace of development of energy policy over the last five years arising from a number of different factors: the changes made in the Single European Act which increased the EC's responsibilities; increased attention to the promotion of competition to reduce costs; a growing concern for the environmental impact of the processing and consumption of energy and, finally, the Maastricht Treaty.

[1] Throughout this policy paper we refer to the European Community or European Union as the EC.

These developments in the EC have focused attention on the issues of competition policy, environmental policy and long-term security of supply (Surrey, 1992). However, progress has been slow and in Chapter 2 Helm argues that one of the most important tasks for EC policy makers, the development of the European energy transmission network, has attracted little attention.

The European Commission on the strength of the Single European Act, published its proposals for a single energy market (SEM) in 1988 (European Commission, 1988b). These proposals were intended to create a unified internal energy market without barriers to trade and competition, not by seeking to introduce co-ordinated energy policies, but rather by extending competition policy to the previously excluded area of energy.

The most significant proposal to date by the European Commission relating to the energy market is the recommendation on common rules for internal markets in electricity and natural gas (European Commission, 1992). Negotiations on these proposals have been hampered by the divergent nature of the energy infrastructures across member states which have led, in turn, to pronounced differences in domestic energy policies.

There has been some progress on the adoption of directives on competition and public procurement in the energy sector. Transit directives, to facilitate the exchange of power and gas between utilities, were adopted in both the electricity and natural gas sectors in 1990 and 1991 respectively. The EC has also adopted a directive on price transparency in the gas and electricity utilities in 1990, which requires notification of the rates charged to all categories of customers.

A more contentious proposal in the "market-oriented" approach is the issue of third party access (TPA) to the European gas and electricity networks. TPA would oblige companies operating transmission and distribution networks for gas and electricity to offer terms for use of the grid to individual consumers or other distribution companies if there is capacity available (European Parliament, 1992).

Four general principles lie behind the EC Commission's approach to developing Community energy policy.:

- the need for a gradual approach,
- the principle of subsidiarity,
- the need to avoid excessive regulation,
- dialogue and consultation.

The first principle recognises the need to allow the economy generally, and industry in particular, time to adjust in a flexible and orderly manner to major policy changes. Owing to their capital intensity, energy infrastructure and other energy intensive industries require long lead times for planning and construction. As a result, uncertainty, which may call into question the likely rate of return on future investment, must be minimised by clearly setting out the levels of liberalisation to be achieved at each stage.

The subsidiarity principle, in theory, enables member states to opt for the system of liberalisation which best suits their natural resources, their industry infrastructure, and their overall energy policies. New regulations will be necessary to complete the internal market but these should replace rather than supplement existing instruments. An additional proposal is the introduction of the concept of unbundling; that is the separation of the production, transmission, and distribution operations of utilities.

Measures are envisaged to ensure that fair competition prevails as national energy markets are opened up. These include proposals on:

- *The Control of State Aid* - to ensure that distortions to competitive energy markets caused by state subsidies are controlled across member states. To allow for national security concerns, continued aid of a *reserved sector* would be authorised. The percentage share of total electricity represented by this *reserved sector* would decline over time;

- *Electricity and Gas Transmission Infrastructure* - given that the internal market is likely to create increased European cross-border demand for gas and electricity. Supply will be unable to respond unless transmission infrastructures and interconnections are developed at a sufficient pace.

The proposals related to the electricity sector include recommendations on the opening up of generation to competition and the role of member states on security of supply. The latter involves permitting national authorities to order priority utilisation of indigenous sources of electricity generation for up to 20 per cent of needs (15 per cent after 2000); permission to order priority use of energy sources that are renewable or are based on waste or cogeneration (not exceeding 25 MW each) in return for a reasonable price. The proposals for the gas sector parallel those for electricity.

In addition to EC directives and proposals on the energy sector, there are a number of important environmental proposals that have significant implications for energy use. These include the 1988 EC Large Combustion Plant directive on sulphur emissions for electricity production (European Commission, 1988a) and proposals to limit the Community's carbon dioxide emissions in the year 2000 to their 1990 emission levels (European Commission, 1991a). This latter proposal includes a provision for a combined energy - carbon tax.

The EC also highlights the role of energy efficiency measures to help achieve targets. This focus on efficiency is part of the Community's "no regrets" strategy for dealing with the potential problem of climate change. Specific programmes are in place to improve energy technology diffusion and energy efficiency measures and to harness alternative power sources. The EC is also helping to fund the expansion of the energy transmission network in Europe through programmes like REGEN. Part of the cost of financing the gas pipeline between Ireland and Great Britain is being met under this programme.

The European Commission (1991b) set out the European Energy Charter in order to address the strategic issue of long-term supply security. The Charter, made in conjunction with the countries of Eastern Europe and the former USSR, is an attempt to secure an expanding supply of reasonably priced oil and gas for the EC in return for investment, technology and hard currency for Eastern Europe.

Taken together the EC agenda on energy policy poses major challenges for the energy sector in Ireland. It will be a factor for change in the sector and it can be expected to form the agenda for domestic policy for the rest of the decade.

This Policy Paper

This Policy Paper considers a number of aspects of Irish energy policy in the light of developments within the EC.

In Chapter 2 Helm discusses the rationale for EC and domestic energy policy, the role of competition and the importance of developing Trans-European networks. Market failures pervade the energy sector and, as a result, while government intervention may frequently be unsatisfactory, intervention remains essential. The Chapter stresses the need to develop a European transmission network. Because the development of such a network may not be in the interests of the current players in the energy market there is a need for the EC, using its new powers under the Maastricht Treaty, to intervene. It suggests that this issue, the development of networks, may be more important than the question of Third Party Access to existing networks.

Chapter 3 by Fitz Gerald and McCoy, is concerned with the full range of developments at the EC level as they affect the Irish economy. This Chapter concludes that the draft EC directives are pushing Ireland in the direction it would probably wish to travel. There is both the possibility and the need to introduce competition into the energy and gas systems. However, this will be difficult given the small size of the energy system of the Republic. In the case of electricity, competition can best be introduced by allowing new operators to build and operate generating stations. The size of these generators should not be such as to dominate the system. In the case of gas, the transmission system should be open to use by third parties. In the long run the energy transmission systems on the island should be fully integrated to permit proper competition. It would not be desirable to privatise the elements of the energy system which are essentially natural monopolies.

Users of energy should be charged the full price of energy. Given the existing tax distortions, competitiveness is better enhanced through measures directed at the labour market than through subsidising energy. The taxes and subsidies on energy should be reformed to reflect the environmental cost of different fuels.

The importance of improving energy efficiency is emphasised by the EC. Chapter 4 by Scott describes the results of a study of energy efficiency in the household sector. It uses the results from a survey of households to examine the extent to which the opportunities for energy saving are exploited. It finds that the behaviour of households in the past has been irrational - failing to exploit profitable opportunities for saving energy indicating some market failure.

Scott suggests that, in the light of these results, a policy of using taxation alone to promote energy efficiency and minimise environmental damage will not be sufficient. There are a number of reasons for this apparent "market failure": a lack of information; problems arising from housing tenure, in particular in rented accommodation, which mean that the gains from investment in energy saving do not accrue to the investors; problems in financing the necessary investment.

The result of increased competition and environmental regulation will be serious pressure on the peat industry. Chapter 5 by Nic Giolla Choille examines the possible impact of a carbon tax on the peat industry. It identifies the current cost of using peat to generate electricity over other alternative sources at around £30 million. Earlier studies suggested a higher figure because they failed to take account of the fact that much of the expense is a sunk cost; it would not disappear even if the peat industry closed.

The introduction of a carbon tax would substantially increase the cost to the Electricity Supply Board (ESB) of using peat, providing a stronger incentive to switch to alternative fuels. This reflects the fact that emissions from burning peat contain more carbon dioxide (a greenhouse gas) per unit of electricity generated than for other fuels used by the ESB. However, the burden to the nation of subsidising peat electricity through electricity prices would not be changed by the tax.

Chapter 6 by Conniffe examines the relationship between energy demand and the growth in GDP and prices. Energy elasticities are necessary inputs to the types of analyses appearing in other papers in this publication. However, the estimates of elasticities are actually far from soundly established and there are even disagreements in the literature on how elasticities ought to be estimated.

Taken at face value, estimates of the GDP elasticity made in the conventional way for Irish data seem to indicate large decreases over time. Chapter 6 investigates the possibility that the apparent changes in estimates may be largely illusory, the consequences of hidden price effects and inadequately clarified technological advances, as well as deficiencies in the methods of measuring aggregate energy quantity and price.

The overall conclusion drawn from the analysis described is that it would be unwise to take the current GDP elasticity as much below unity. Future energy demand is likely to grow in line with economic growth, unless there are further extreme price hikes of the order of the 1973-74 and 1979-80 oil crises.

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Chapter 2

ENERGY POLICY IN THE EUROPEAN CONTEXT

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1. Introduction

Energy policy has traditionally been a national activity. Governments have been concerned to ensure that national supplies of energy are secure and sufficiently diverse to prevent disruption from price or supply shocks. Self-sufficiency has been an aim in many countries: France's nuclear programme, Britain's plan for coal in the 1970s, and Ireland's development of peat and gas are examples.

This national preoccupation is gradually breaking down for two reasons. First, technical change has increased the prospects for international transmission of gas and electricity, so that the network natural monopolies are being redefined at the European rather than national level. Second, the process of European political and economic integration in general, and the internal market in particular, is increasingly providing a European focus for the consideration of questions of energy policy. The security of European supplies is gradually becoming a more important question than the security of national supplies.

These developments are evolutionary, and will depend for their effect on matters of national geography and national political will. Nevertheless, the trend is probably irreversible. This Chapter considers some of the dimensions of energy policy in this European context, and focuses in particular on two questions: the promotion of competition and the development of trans-European networks.

The Chapter is structured as follows. Section 2 sets out the underlying rationale for energy policy, the market failures. Section 3 considers the role of competition and the implications for market structure. Section 4 considers the interconnections issues and the conditions required for the development of trans-European networks. Finally, Section 5 presents a number of conclusions.

2. The Rationale for Energy Policy

The rationale for energy policy is based upon two premises: that energy markets "fail" in providing an appropriate allocation of scarce resources, and that government intervention can improve upon these failures. Traditionally, those in favour of activist energy policies concentrate on the former; those against focus on the latter. A balanced pragmatic approach takes both into account.

Market failures

The energy sector is characterised by multiple market failures. These can be divided into static and dynamic efficiency issues. On the static front, there are three substantial failures: natural monopoly, co-ordination and pollution. Left to its own devices, a private market will be dominated by monopoly or oligopoly, and vertical integration. Pollution will be excessive, and there is no guarantee that dispatch will be at least cost. For these reasons, final consumer prices are regulated in virtually every developed country, environmental policy puts constraints on emissions, and, even in the English and Welsh system, electricity despatch is regulated through a compulsory pool.[1]

Energy policy has also been significantly concerned with dynamic efficiency. It has been a conventional wisdom that private markets will be unlikely to invest in the "right" amount of investment, or in a sufficient degree of diversity. The explanation for these market failures is complex. It relies on an analysis of competition between oligopolists and the externality associated with the avoidance of supply interruption. Purchases of electricity and gas are rarely physical contracts: the supply and demand are typically system-wide in nature and therefore introduce an element of public good. Consumers find it hard to signal the insurance value of security and supply, and generators face downside risk from the prospect of over-supply. There are rarely import opportunities rapidly available to meet demand surges.

In theory, entry into the market will come wherever future potential demand exceeds supply. In the England and Wales electricity system, this is supposed to work through the loss of load probability (LOLP), which provides information against which entrants can form rational expectations. In practice, there are two difficulties. These are the presence of entry barriers, and the problems associated with the characteristics of power station investments. The electricity industry in particular is far from meeting the conditions of a contestable market. Hit-and-run entry is impossible, and sunk costs are high.

[1] The pool is a spot market in electricity. Each generator bids in prices (not costs) for half-hour periods one day ahead. A dispatch order is derived, and generators are paid on the basis of the system marginal costs. See Helm (1991)for a more extensive treatment.

From the perspective of the generator, investments are made on the basis of assumptions about the future supply and demand balance over the life of the investment. The possibility that supply may exceed demand in the future creates risk. Therefore, generators seek protection against this possibility, through vertical contracts or vertical integration. In order to encourage generators to invest, consumers need to commit to absorb the costs. In most electricity markets, this is achieved through vertical integration and franchises. This is a normal market structure in electricity, deviating markedly from the competitive paradigm.

Government failures

Although there is some disagreement about the concentration of investment on similar types of power stations and some controversy about the co-ordination of capacity, most parties to the energy debate agree that market failures are pervasive. However, the main controversy in recent years has focused on government failures. The history of energy policy is littered with examples of policy "failures". In England and Wales, the nuclear programme in general, and the Advanced Gas Cooled Reactors (AGR) programme in particular, have been extensively criticised. Operating costs and the scale of power station investments in the public sector were excessive.

The various government failures can be divided into two groups: those associated with government ownership and those associated with energy policy. Nationalisation has created particular problems. The inability over three decades to develop control mechanisms, the pervasive intrusion of macroeconomic expenditure controls on investment projects, and the biasing of investments towards domestic technology have contributed to the significant additional costs.

The failures of energy policy are harder to evaluate. Government interventions over the choice of fuel, and in particular the protection of domestic coal industries in Britain and West Germany, have rested on much wider political objectives. The dislocation cannot be judged purely on grounds of industry efficiency costs. Japan and France's drive for nuclear power have been governed by national security considerations, in France's case explicitly so. Nevertheless, the exposure of investment decisions to the vagaries of electoral geography has resulted in higher costs, and it is to be questioned whether these have always been justified.

A Pragmatic approach

Market and government failures vary from case to case. There is no a priori correct answer to the appropriate balance. Failures vary too across time. In periods of excess supply and low international energy prices, the extent of private investment failures is obviously much less. During the 1980s in Britain, the main issue was the static one of costs, and competition provided an appropriate response. The investment issue simply did not arise. In the late 1990s, the focus will probably shift to investment, and hence policy will shift to dynamic efficiency questions.

More generally, within countries, grids and transmission systems are largely mature across the European Community. However, between countries, the connections are immature. Thus, whilst national governments focus on the utilisation of existing systems, European policy is more concerned with the investment questions.

3. Competition and the Structure of Electricity and Gas Industries

Competition policy towards the energy sector has been gradually applied in a number of European countries. The application in the UK has gone further and faster than other countries. It therefore provides an example which has greatly influenced the development of the Internal Energy Market programme.

The main reason for introducing greater competition into electricity markets is as a method of regulating the markets. Rather than attempting to place controls on dominant firms, the presence of competitors, actual or potential, limits the ability to raise prices above costs and to select inappropriate investments.

The introduction of competition is, however, a complex process. It requires two parallel developments: the separation of natural monopoly from artificial monopoly, and the opening up of artificial monopoly to competition. This strategy has been partially adopted in the England and Wales electricity and gas markets. In electricity, supply has been separated from transmission and distribution in a regulatory sense (though only partially through structural change), and the artificial generating monopoly has been divided into three companies. The remaining natural monopolies are isolated into twelve regional companies and one national one, and regulation is applied to each separately.

The changes introduced at privatisation were designed to bring about a gradual transition to a fully competitive market over an eight year period to 1998. During this period, new entry was to be encouraged into generation, and supply was to be gradually deregulated by dropping the franchise limit in 1994 and abolishing it in 1998.

These structural changes - "unbundling" in European jargon - addressed questions of ownership. They have, however, only partially addressed the questions of control. Since privatisation, there has been a substantial "dash-for-gas". However, contrary to the British government's claims, the new entrants in fact represent only minimum extra competition: all significant projects are supported by back-to-back contracts with the regional electricity companies (RECs)[2] and in some cases these are further underwritten by equity stakes. In

[2] The RECs are the successors to the Area Boards which existed in the nationalised industries. They are responsible for distribution of electricity within their franchise areas, and supply to franchised customers within their area below 1 MW (to fall to 100 KW in 1994).

effect, there has been a process of vertical integration through contracts. Investment by new generators, it transpires, will only take place if long-term commitments are entered into on the basis of the RECs' franchise markets, naturally or legally defined.

Even these REC-based entrants have required regulatory protection. Terms of access to the system have been fixed, and the regulation of transmission tariffs will affect their ability to compete for a dispatch slot. Accounting separation, and the assignment of costs between supply and distribution, has also been a significant regulatory issue.

The implication for European policy of the England and Wales experiment are several. Unbundling, *per se*, will not create competition. It will not arise spontaneously. Rather, regulation for competition will be required. It is the almost complete absence of appropriate regulatory arrangements in the European Commission's proposals for the Internal Energy Market which will undermine its effect. Furthermore, even if unbundling were to facilitate the promotion of competition, if accompanied by appropriate regulation, the resulting market would tend to re-integrate through contractual arrangements in order to underwrite the sunk costs of new power station investments. In other words, entrants will want some protection from competition in order to avoid a competitive threat. This paradox has so far eluded the regulators in England and Wales, and resulted in the apparent confusion that competition is measured by the number of "competitors". There is a considerable difference between competition in the static sense (and therefore through a pool) and dynamic competition where generators compete for longer-term contracts.

4. Interconnection and European Regulation

The shift in the definition of the national networks to the European level is at present being conducted through a series of bilateral links between national utilities. The links reflect the interests of dominant incumbents. Thus Electricité de France has constructed links with most of its neighbours to export its nuclear surplus. The UK has to date refrained from linking its North Sea gas network with the European network in pursuit of national gas self-sufficiency, though this is now under active consideration.

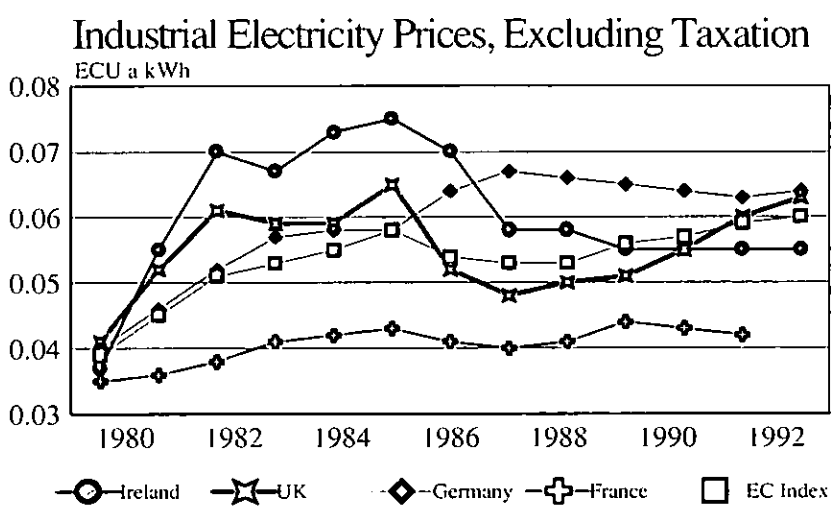
There are several related problems with this *ad hoc* approach. The first is the classic "co-operation versus self-interest" trade off. Europe as a whole would be much better off if a Europe-wide approach were adopted. Capacity margins could fall as countries backed up each others' systems. Diversity could be provided *between* countries, rather than each individually opting for mixed fuel sources. Economies of scale could be exploited through access to larger market areas. However, from each individual country's perspective (and often each utility's too), it is better if others co-operate and it pursues its own self-interest. Britain may want to enjoy the benefits of security of supply provided by excess investment in others' systems, but refrain from providing a reciprocal service itself. The French electricity link, and the tardiness in developing a European North Sea gas network, are examples.

A further problem with the national approach is that the system develops in a piecemeal way. Each connection is considered in isolation, without attention being directed to the costs and benefits to the system *as a whole*. In this respect, the network is a public good: private markets typically under-provide public goods.

The European Commission's approach has to date given little attention to these network issues. Its focus has been on narrower issues of competition, gradually opening up existing networks to greater access. Its programme of directives have taken an evolutionary approach, starting with transparency in prices, moving on to third party access, and eventually to unbundling.

It has not yet had much success. The price level differentials between member countries remain large. These price dispersions are even greater for particular classes of customer. The consequences for the internal market in related energy intensive industries is considerable, as Figure 2.1 shows. For some industries, competition is essentially determined by electricity and gas prices - for example, in aluminium, steel and chemicals.

Figure 2.1



Source: International Energy Agency Statistics (prices converted at current ECU exchange rates). EC Index constructed by OXERA

The main reason for the continuation of these price differences is the lack of interconnections and rights of access. Without interconnection, transfers cannot take place. But even with interconnections, prices can only then be harmonised if competitive entry is permitted and supported by competition law. The Internal Energy Market programme addresses the former, but not the latter.

There is, however, a significant change in approach signalled by the Maastricht Treaty. Article 129b of Title 7 provides for the development of Trans-European networks.[3] The exact terms are:

Article 129b

1. *To help achieve the objectives referred to in Articles 7a and 130a and to enable citizens of the Union, economic operators and regional and local communities to derive full benefit from the setting up of an area without internal frontiers, the Community shall contribute to the establishment and development of trans-European networks in the areas of transport, telecommunications and energy infrastructures.*

2. *Within the framework of a system of open and competitive markets, action by the Community shall aim at promoting the interconnection and interoperability of national networks as well as access to such networks. It shall take account in particular of the need to link island, landlocked and peripheral regions with the central regions of the Community.*

The full implementation of Title 7 will require major new initiatives, and indeed the Commission has already begun to support particular projects like the gas interconnector between Ireland and Britain. The problem at present is that the Commission is approaching the network investment problem on a case-by-case basis. It has not addressed the overall system requirements. This is in stark contrast to the Japanese approach, and indeed to the approaches adopted in individual member countries.

It has been argued that these questions can be addressed by the application of the principle of subsidiarity: that regulation can be delegated to the national level, and that in consequence there will be regulatory competition. Those countries which apply the best regulatory approaches will, it is argued, gain a competitive edge over those which take a more restrictive policy.

This argument has beguiling political attractions. It does not however convince since, as indicated in Section 2 above, the provision of networks is a public good: all member countries could benefit through a European-wide approach.[4]

5. Conclusions

Market failures pervade the energy sector. Although there have been numerous examples of government failure, the case for an appropriately designed energy policy is persuasive. That policy should be defined at the level of natural

[3] Article 129c provides the steps required to meet article 129b.

[4] The nature of regulatory competition is also open to its own failures. These are described in Helm (1993).

monopoly appropriate to the energy sector: in electricity and gas, this is increasingly at the international level. This rise in scale is partly a function of technology, partly of market demand, and partly of primary fuel locations.

The provision of network infrastructures has considerable public good characteristics. They will, typically, be under-provided by the private sector. They will also be under-provided if national governments pursue national energy policies. The development of the European electricity and gas grids is appropriately designed at the European rather than national level: it provides a clear example where the principle of subsidiarity is not appropriate.

Infrastructure networks are essential to European competitiveness: the ability of European firms to compete with US and Far Eastern rivals depends upon access to competitively priced energy. Failure to develop energy networks results in higher costs associated with national security capacity margins and national diversity programmes.

These concerns are recognised in the Maastricht Treaty. Title 7 explicitly refers to the need to develop policy in this area. However, the Treaty recognition does not appear to have yet been grasped by the European Commission. The Internal Energy Market, in focusing on third party access (TPA) and unbundling has only tangential relevance: indeed it is possible to argue that these largely static concerns may actually reduce investment incentives in new infrastructure.

The Internal Energy Market has faltered: the opposition of European utilities to TPA has resulted in a stalemate. In order to take matters forward, the European Commission could renew its efforts to see through the directives once the political climate becomes more favourable. A superior approach would be to take the current stalemate as an opportunity to go back to the drawing board: to consider what should constitute a European energy policy appropriate to the competitiveness of the European economy in the next century. The Maastricht Treaty, in Title 7, provides a good basis. If TPA and the rest of the Internal Energy Market were set in this context, then the Commission might have a greater chance of success.

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Chapter 3

ISSUES IN IRISH ENERGY POLICY

John Fitz Gerald and Daniel McCoy

1. Introduction

In a modern market economy there are many sectors which develop and grow without major state involvement and without specific targeting by public policy. However, in almost all countries the energy sector attracts special attention from public policy. This is true, not just at a national level, but it is also true at the level of the EC. This Chapter considers the implications for Ireland of a series of proposals, put forward by the EC Commission, which potentially affect the energy sector.

The need for a public policy on energy is justified on the grounds of the existence of market failures in the sector. In particular, increasing returns to scale in the energy sector have resulted in the development of monopolies in most EC economies. The potential for increasing returns arises from the technical characteristics of the electricity and gas industries and, at an early stage in the development of the energy sector, it resulted in intervention by the state. In many cases this took the form of the creation of a state owned firm to exploit the benefits arising from increasing scale. However, government intervention, both nationally and internationally has in the past failed to meet its objectives, often as a result of political expediency see, for example, Helm (1991).

In Ireland the government plays an active and prominent role in the energy market by state-ownership of the main utility monopolies, influencing decisions on fuel choice and making strategic decisions on issues of security of supply. These issues are examined in this paper.

The need for an energy policy is justified by the scale of operation in the energy sector and, related to this, the presence of monopolies or oligopolies at different stages in the production process. The presence of significant negative environmental externalities in the energy sector, in any event, calls for state involvement in policy making. The scale of operation and the presence of environmental externalities makes the energy sector very different from many other sectors such as, for example, the manufacture of clothing. In the latter case the normal working of the market is likely to result in an efficient scale of operation without direct government intervention.

As discussed in the first two Chapters, there is an increasing role for the EC to intervene to ensure an efficient operation of the energy market. The impetus for this involvement arises from a number of factors: the global nature of problems of pollution; the completion of the internal EC market; the experience of the successive oil crises of the last 20 years; the desire to reap the benefits from increased scale of operation through interconnection of national systems. Many of these concerns are already reflected in domestic energy policy.

Traditionally, the overall objective of Irish energy policy has been to minimise the cost of energy to the economy. However, there are a number of constraints which must be taken into account:[1]

- The need to ensure security and continuity of supply,
- The need to minimise or reduce environmental damage,
- Certain social considerations - e.g., employment in Bord Na Móna, the state owned peat industry.

In the past energy policy has been more concerned with security and continuity of supply. However, attention is now turning to the issues of controlling the negative effects of monopolistic behaviour and to the environmental side effects of energy use. A reflection of this shift in emphasis is the decision to restructure the ESB into separate business units covering power generation, national grid, customer service, commercial enterprises, and business services.

This Chapter considers the wider implications of developments in the EC for energy policy in Ireland. It does not aim to make a comprehensive statement on energy policy; for example, many of the issues for policy concerning the domestic oil market are not considered here (see DKM, 1991). In Section 2 we give a brief description of the important characteristics of the Irish energy sector.

[1] In *Energy Ireland*, published by the Government in 1978, the main elements of energy policy were specified:
a. Optimum development of indigenous resources.
b. Access to the cheapest markets for imported energy supplies.
c. Security of supply by diversification of sources.
d. Promotion of economy in the use of fuels.
e. Stock-piling against emergencies.
f. Protection of the environment.
g. Encouraging exploration for hydrocarbons and uranium.
h. Participation in research to discover and develop new energy sources.

In Section 3 we examine the likely energy requirements of the economy for the rest of the 1990s. Section 4 discusses the importance of security of supply and Section 5 considers the interaction of energy policy and the environment. The issues of competition and ownership and pricing and taxation are dealt with in Sections 6 and 7. Finally, conclusions are presented in Section 8.

2. *The Irish Energy Sector*

Special features

Irish energy policy is affected by the country's endowment (or lack of endowment) of natural resources, the history and relatively small scale of the economy. The absence of coal or oil meant that, since the nineteenth century, energy was primarily derived from imports and, as a result, was generally more expensive than in certain other parts of Northern Europe. This affected the pattern of economic development. Ireland has no tradition of industries requiring major energy input such as steel, smelting and process chemicals. Any industry which required cheap energy tended to gravitate to regions of Europe with an abundance of energy: in the nineteenth century the coal deposits of Britain and Germany provided the basis for expansion of energy intensive industries. More recently, Scandinavia, with cheap hydro-electricity, has attracted such ventures.

The absence of major domestic energy sources posed special problems for the Irish economy during the Second World War. The experience of energy shortages during the war and the relative inability of the government to take remedial action had a lasting effect on domestic energy policy. In the years after the war ended strenuous efforts were made to reduce this dependence on imports by developing domestic energy sources, in particular the use of peat to generate electricity. The importance attached to security of supply in Irish energy policy was reinforced by the temporary shortages of oil during the Suez crisis in 1956 and during the first and second OPEC oil crises of the 1970s. The result of these experiences is that considerable attention is devoted to security of supply in developing energy policy. In many cases this requirement takes primacy over measures to minimise the cost of supply of energy. Examples of this emphasis on security are the policy of maintaining a domestic refinery, the policy of diversifying fuel supplies, and the construction of a gas interconnector to the UK before it is needed to replace the indigenous gas resources in the Marathon field.

The Irish economy over the last 35 years has progressively opened up to the outside world. The freeing of trade, the extensive inflow of foreign capital and the free movement of labour since the last century have all contributed to the character of recent economic development. However, the isolated nature of the Irish electricity and gas systems remains an important feature of the system. While the installation of a gas interconnector to Britain will modify this situation, the need to maintain security of supply means that the scope for using this one interconnector may be limited.

A further feature of the isolation of the domestic energy system, both gas and electricity, is the absence of effective interconnectors between the Republic and Northern Ireland. Terrorist action in the mid-1970s closed the existing electricity interconnector and it has not been reopened since. This issue is dealt with later in this Chapter.

Finally, the density of population in Ireland is quite low by the standards of Northern Europe. Industrial policy has also promoted a dispersal of industrial activity throughout the country, away from the major traditional industrial centres of Cork and Dublin. The result of both these factors has been a significant overhead pushing up the costs of distribution for electricity, gas, and oil.

Existing structure

The imperative to establish a secure supply of energy and the need to promote domestic economic activity resulted in the development of a series of peat-fired electricity generating stations in the years after the Second World War. However, the electricity generated from peat proved to be more expensive than that from imported oil or coal. As discussed in Chapter 5, the harvesting and processing of the peat is quite labour intensive compared to the process of generating electricity from oil or gas. As the world real price of oil fell in the 1950s and the 1960s the cost penalty of using domestic peat increased. The rapid rise in oil prices after 1973, which also affected the price of coal, temporarily reduced the cost penalty for peat generation and there was some increase in peat generating capacity. The fall in oil prices after 1986 has reversed this situation.

Beginning in the 1970s and continuing into the 1980s there was considerable hydrocarbon exploration activity in Irish waters. A significant gas find was made in the early 1970s by Marathon off the South coast and this came on stream at the end of that decade. Production reached a peak in 1983, accounting for almost 20 per cent of domestic primary energy requirements. While traces of hydrocarbons were discovered at other locations these proved too expensive to exploit, even when real oil prices were higher in the mid-1980s.

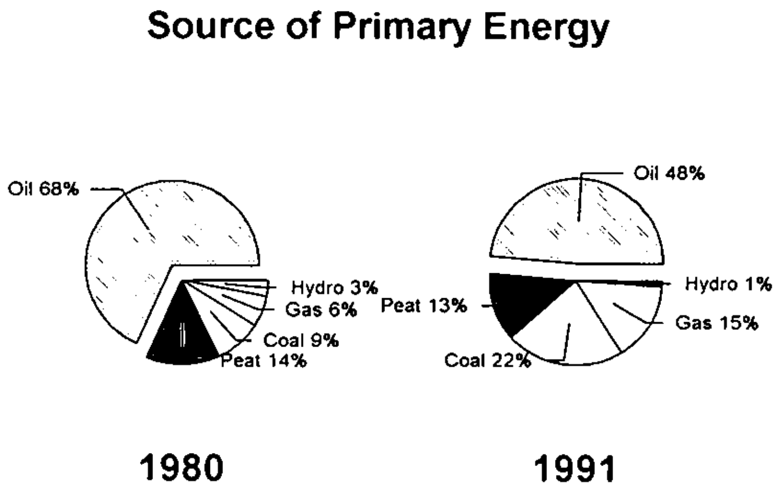
The Marathon gas field and the smaller Ballycotton field are likely to be exhausted around the end of the century, substantially increasing Ireland's dependence on imported energy. By the Autumn of 1996 supplies may not be sufficient to meet peak demand from the ESB. With a developed gas distribution system in place, this will mean that there will be a need to import significant quantities of gas towards the end of the century. The fact that construction of the pipeline is nearing completion, though the requirement for imports will not occur for a number of years, arises from the need to ensure security of supply.[2]

As a result of the indigenous gas finds and a lagged response to changes in relative prices there was a major change in the sources of energy used in Ireland

[2] A significant part of the funding is also coming from the EC REGEN programme. This funding might not be available for an alternative scheme.

over the 1980s. This is shown in Figure 3.1. The availability of natural gas led to a switch in consumption. It was used, first for electricity generation and later by other sectors of the economy. There was also a major switch to solid fuel by the electricity generation sector. This change occurred as a result of the oil price shocks of the 1970s which highlighted the dependence of the economy on oil. The need to diversify energy supplies and the change in relative prices resulted in the decision to develop the coal-fired electricity generation station at Moneypoint at the end of the 1970s. The net result was that oil, which had accounted for almost 70 per cent of primary energy requirements in 1980, was reduced to meeting under 50 per cent of requirements by 1991.

Figure 3.1



Source: Department of Energy, Energy Balance Sheets.

By 1991 gas accounted for around 15 per cent of primary energy requirements. In addition, a quarter of total gas production was used as a feedstock for the domestic chemical and fertiliser industry. When taken together with peat and a small amount of domestic hydro-electricity, around 30 per cent of domestic consumption of energy was met from domestically produced primary energy in 1991.[3]

The distribution of final consumption of energy is shown in Figure 3.2. These figures differ from those in Figure 3.1 in that they show the consumption of the energy in its final "transformed" state, after it has been turned into electricity, petrol, etc.. Some of the primary energy is used itself in the transformation process. Almost 22 per cent of final energy consumption is met

[3] This figure excludes natural gas used as a feed-stock.

from solid fuel - coal and peat. Over half of the coal and the vast bulk of the peat is used for heating by the residential sector. Ireland is unusual in the extent to which solid fuels are used for heating. Just over half the oil is used in the transport sector with most of the rest being used in the commercial and the industrial sectors.

Source: Department of Energy, Energy Balance Sheets.

Figure 3.2
Final Consumption of Energy

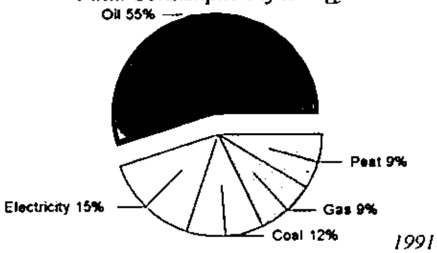
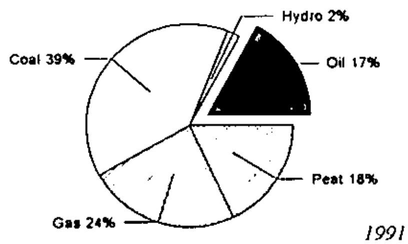


Figure 3.3
Fuel for Electricity



As can be seen from Table 3.1, the sources of primary energy in Ireland are broadly similar to those in the rest of the EC with one exception. Whereas Ireland depends on peat for just under 15 per cent of its primary energy, in the rest of the EC nuclear energy plays the same role. This difference has special significance when considering the environmental impact of Irish energy consumption (See Fitz Gerald and McCoy, 1992).

Table 3.1: *Primary Energy Consumption by Fuel (per cent)*

	Coal	*Peat*	*Oil*	*Gas*	*Nuclear*	*Other*
Ireland	22.4	13.2	48.3	15.4	0.0	0.7
EC	21.0	0.0	44.8	18.3	14.3	1.6

The data for Ireland are for 1991; the data for the EC are for 1989.

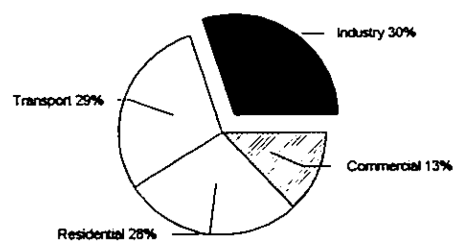
Electricity accounts for around 15 per cent of final energy consumption. Within total electricity consumption the residential sector and the industrial sector each accounted for around 39 per cent of the total. Over the 1980s the share of consumption of electricity by the residential sector tended to decline as consumption of natural gas by that sector picked up. However, both the share and the absolute consumption of electricity by the industrial sector increased over the period.

Electricity plays a vital role in the energy sector and the current sources of primary energy used by that sector are shown in Figure 3.3. Coal accounted for almost two-fifths of the fuel used[4]; oil accounted for under one-fifth. This is a radically different situation to the 1970s when the bulk of electricity generation was dependent on oil.

The final consumption of energy by sector is shown in Figure 3.4. Industry, transport and the residential sectors each account for around 30 per cent of total energy consumption. The commercial sector accounts for the rest - just over 10 per cent. As can be seen from Table 3.2, this pattern of consumption is not very different from that of a number of other Northern European countries such as Belgium, France, Germany and the UK. A notable exception is Spain where the residential and commercial sector accounts for a much smaller share of consumption, possibly reflecting lower heating requirements in a milder climate.

Figure 3.4

Consumption of Energy by Sector, 1990



Source: Department of Energy, Energy Balance Sheets, Final Consumption.

Table 3.2: *Energy Consumption by Sector, 1989 (per cent)*

	Belgium	*France*	*Germany*	*Ireland*	*Spain*	*UK*
Industry	36.3	29.1	34.8	29.7	34.9	25.3
Transport	25.0	32.1	27.8	28.6	42.2	31.9
Households & Commercial	38.8	38.8	37.4	41.7	22.9	42.8

Source: EUROSTAT. Note: Data for Ireland are for 1991.

The ultimate objective of Irish energy policy is the minimisation of the cost of energy supplies to the Irish economy. While the possibility of trade in oil and coal means that, subject to transport costs, market forces should ensure that prices in Ireland are competitive with those elsewhere in Northern Europe[5] this is not necessarily the case for electricity and gas. In both these cases the isolated nature of the Irish energy supply system has in the past restricted the possibility of

[4] Measured in tonnes of oil equivalent - TOE.

[5] As discussed in DKM (1991) there are competition problems with the domestic distribution of oil products resulting in substantially higher retail prices in Ireland than in our near neighbours.

competition and it has potentially imposed additional costs. However, gas is in a more competitive environment than electricity as it faces competition in all markets from alternative fuels. This is reflected in the pricing policy of Bord Gais Eireann (BGE), where prices are set in relation to the price of substitute fuels. Electricity, on the other hand, is in many cases the only fuel suitable for particular uses having an effective monopoly of such markets.

Table 3.3 shows a comparison of the tax exclusive prices of electricity and gas to users for a range of countries in 1991. The prices have been converted to Irish pounds to facilitate comparisons. These data suggest that Irish electricity prices are certainly not out of line with those of other Northern European neighbours, in spite of the isolated nature of the Irish system. Generally German prices are high, reflecting the relatively costly use of domestic supplies of coal and the cost of protecting the environment. A report for the European Parliament (1992) estimates that electricity prices in Germany are raised by 10 per cent as a result of strict environmental controls. France has in each case the lowest price reflecting the preponderance of nuclear generation in that country.[6]

Table 3.3: *Relative Energy Prices (Tax Exclusive), 1991, £IR*

	Belgium	*France*	*Germany*	*Ireland*	*UK*
	£IR per kWh				
Electricity - Households	0.09	0.07	0.08	0.07	0.07
Electricity - Industry	0.04	0.03	0.05	0.04	0.04
£IR per 10^7 Kilocalories (TOE)					
Gas - Households	222.2	249.3	217.8	264.7	208.4
Gas - Electricity Generation	85.4	NA	89.4	59.4	NA

Source: International Energy Agency, *Energy Prices and Taxes*

For gas, Irish charges to consumers are, with one exception, the highest of the countries examined, though the difference is not very marked. It is difficult to obtain comparable data for prices to industry but the comparisons in DKM (1991) using EC data suggest that the price difference is not as great as some published figures might suggest. By contrast, the price of gas supplied for electricity generation was very low when compared with the situation in Belgium and Germany.

The relatively satisfactory price situation for gas and electricity in 1991 contrasts with the situation in the mid-1980s when Irish prices were well above

[6] It is probable that the French prices are biased downwards as they do not fully reflect the long-run cost of nuclear energy due to the very large cost of decommissioning.

those in neighbouring countries. This may have been partly due to relative inefficiency. However, an important reason for the difference was undoubtedly the cost of funding a rapid expansion in productive capacity in electricity and in distribution of gas. [7] If pricing were done on the basis of long-run marginal costs then prices would show less variability over time. It would appear that current prices are below the level of long-run marginal cost. As a result, as new capacity is installed over the 1990s, financing costs and, therefore, prices will have to rise. Thus the favourable situation with regard to electricity prices is likely to deteriorate over the rest of the decade.

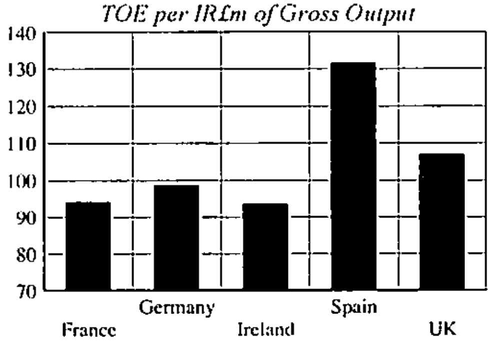
This cyclical pattern in relative electricity prices arises from the combination of the pricing policy adopted and the spasmodic nature of investment in a small isolated system. When considering the effect of the structure of the energy sector on Irish competitiveness this must be taken into account.

As outlined above, while energy prices in Ireland may at present be comparable with those of our Northern European neighbours this has not always been the case. Energy intensive industries did not establish in Ireland because it never had supplies of low cost energy and the Irish industrial structure reflects this. Despite this, as shown in Figure 3.5, the difference between the energy intensity of Irish industry and that of our neighbours is now quite small. As a result, the energy needs of Irish manufacturing are now not very different from those of other EC neighbours.

Figure 3.5

Energy Intensity of Manufacturing

TOE per IR£m of Gross Output



Source: IEA, Energy Balances; UN, Industrial Statistics; Department of Energy, Energy Balance Sheets; CSO, Census of Industrial Production.

This similarity of energy intensity, despite the absence of traditional energy intensive industries, seems surprising and it requires further study. Possible explanations are the small scale of most Irish plants and the limited usage of gas

[7] As forecasted in Scott (1980) the expansion of electricity capacity was much greater than was warranted by growth in demand both *ex ante* and *ex post*.

by Irish industry compared to industry in other Northern EC members. The small scale of plant means that there is little scope for combined heat and power generation, an important feature of some major plants in the other countries examined.

While the presence of major domestic supplies of primary energy in the UK and the Netherlands is an obvious contrast with the situation in Ireland, the other two major factors which make the Irish energy sector unusual are its dependence on fossil fuels, given the relatively low penetration of gas, and the isolated nature of its gas and electricity sectors. In the rest of this Chapter the importance of these two factors for energy policy is further discussed.

3. Energy Demand in the 1990s

In discussing the future role of Irish energy policy it is useful to make some forecasts of the likely evolution of energy demand and supply over the remainder of this decade. The level of economic activity over this period will be the most significant determinant of energy demand. An outline forecast for the economy over the rest of the decade was prepared using the ESRI medium-term model and a related energy sub-model, broken down by five sectors and five fuel types. This system was used to prepare a forecast of the demand for total primary energy requirements (the data are presented exclusive of electricity). The parameters and elasticity measures used in this sub-model are based on historical relationships between sectoral growth and energy use in the Irish economy over the last 20 years.

Forecasts for primary energy requirements are presented in Figure 3.6 and Table 3.4. These forecasts are based on assumptions about supply considerations, such as the availability of an increased supply of natural gas through the interconnector after 1995, and the likely mix of fuels used in each sector, given security of supply conditions and environmental target constraints. They also assume a moderate rise in the real price of energy over the decade.

This forecast suggests that primary energy demand will increase by over 30 per cent from 1991 levels by 2000. Natural gas is expected to increase its share of primary energy considerably from 15.4 per cent to 23 per cent in the same time period, with peat accounting for less than 10 per cent at the end of the decade due to the retirement of some peat powered stations for electricity. The underlying expectation for this "dash for gas" is that environmental considerations, particularly the prospect of a carbon tax on fossil fuels, and increased competition in supply within the EC will favour natural gas use more than the other fossil fuels. The availability of and demand for non-fossil renewable energy sources, like solar or wind power, are assumed to remain unchanged for the purpose of this forecast, along with the potential for energy efficiency take-up.

Figure 3.6

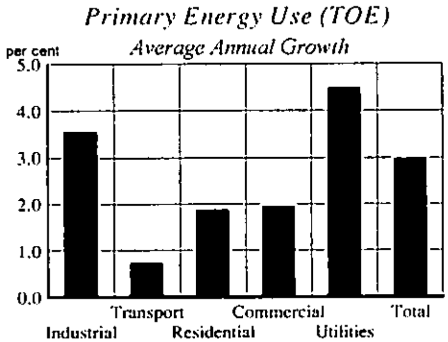


Table 3.4: *Source of Primary Energy, Tonnes of Oil Equivalent (TOE)*

	1991	*2000*
Industrial	22.4	21.0
Transport	13.2	9.6
Residential	48.3	45.6
Commercial	15.4	23.0
Total	0.7	0.8

The annual growth rates in economic activity as measured by GDP and electricity demand are presented in Table 3.5. Relatively modest growth is forecast in the short term, but after 1995 annual growth is forecast to be close to 5 per cent per annum The likelihood of a return to rapid growth will have significant consequences for the energy sector. If we assume that the relationship between electricity demand and economic growth is similar to what it has been over the last number of years then demand will have increased by nearly 50 per cent during this decade. (This relationship is discussed in detail in Chapter 6.) Such a growth scenario, which ignores the potential of the demand-side management and energy efficiency initiatives currently in operation, would suggest the need for a substantial increase in generation capacity.

Table 3.5: *Outline Macro-Economic Forecast 1990-2000*
(average annual growth rates, per cent)

GDP	3.7
Electricity	4.3

4. *Security of Supply*

The objective of security of supply has long been central to Irish energy policy, see Convery, Scott and McCarthy (1983). As discussed above this was an important factor in the development of the peat extraction industry in the post-war years. In the government report *Energy Ireland*, published in July 1978, considerable emphasis was put on this issue. This was not surprising following on the experience of temporary shortages after the first OPEC oil crisis.

Security of supply has traditionally had two components: the availability of primary energy domestically and the diversification of energy sources away from dependence on one fuel or a small number of suppliers. These two aspects of security of supply must be considered together. Just because natural gas comes from an Irish source does not necessarily make it a secure supply given that it is piped through a single pipeline which is vulnerable to accidents. Security of supply is also affected by the possibility of industrial action.

Measured in terms of these two aspects of security, energy policy has been very successful over the last twelve years. The dependence on imported energy has been reduced from around 85 per cent in the late 1970s to around 66 per cent in 1991.[8] In addition, the dependence of the economy on oil has been greatly reduced with the gradual diversification of fuel sources. This diversification has obviously involved a major increase in use of gas; it has also seen a substantial increase in the use of imported coal.

However, while the current situation on the security of energy supplies, measured by the proportion of primary energy sourced domestically, is more balanced than in earlier decades, the situation is likely to change rapidly over the next 10 years. The exhaustion of domestic gas supplies will itself increase dependence on imported energy supplies returning the economy to the position of earlier decades. In addition, in the absence of new investment, the peat industry is likely to decline in importance.

However, the installation of the gas pipeline will allow use of gas to maintain its share of demand, though any major increase could prove risky due to the dependence on a single pipeline as the indigenous sources are used up. The integration of the electricity systems on this island could allow some further increase in the share of gas through spreading the risk of temporary loss of the pipe-line over a larger system.

The issue of security of supply places limits on the extent to which reliance should be placed on a single gas or a single electricity interconnector. While some forms of storage can be used to provide a temporary back-up to the gas supply, the nature of the storage may pose problems. For electricity, storage is not an option. This aspect of security is now much more important than the question of the dependence on imported energy supplies. With the increasing integration of the EC energy system the issue of domestic sourcing is likely to decline in importance. The draft EC directives will contribute to this indirectly. However, just as portfolios of assets are diversified to reduce risk, the need to

[8] This is calculated by taking the total supply of gas and peat as a percentage of primary energy used for energy (non-feedstock) purposes.

maintain diversity of fuel supply to avoid shocks from sudden price changes in the future remains important.

5. Energy and the Environment

Environmental concerns on transfrontier issues like acid rain and the prospects of global warming have gained much prominence over the last decade. The burning of fossil fuels for energy purposes is a major contributing factor in both of these problems. Acid rain is formed by the combination of sulphur dioxide (SO_2) and nitrogen oxide (NOx) emissions in the air, both of these are by-products of energy use, particularly from consumption of coal, peat and oil. The possible consequences of the "Greenhouse Effect", inducing global warming include rising sea-levels and climatic changes. Energy use is estimated to account for almost 50 per cent of man-made sources of greenhouse gases. The main greenhouse gas is carbon dioxide (CO_2) which is also a by-product of fossil fuel use.

International response to these issues has inevitably focused on the energy sector. Environmental targets have been set and timetabled for this decade and these will act as a constraint on Irish energy policy. The problem of acid rain is dealt with at an EC level by the 1988 Large Combustion Plant Directive (LCP), which has targeted reductions in SO_2 emissions by 1993. Ireland received a higher ceiling limit for the power generation than the 1980 baseline level due an allowance for the then unbuilt Moneypoint plant. The ceiling under this directive for utilities is 124,000 tonnes of SO_2 and our forecasts, presented in Table 3.6, would suggest that this 1993 target will be easily met (this assumes that coal with a 1 per cent sulphur content is used for electricity generation). In addition to obligations under the LCP directive, Ireland signed the Helsinki Protocol in 1990 at the beginning of its presidency of the EC. This protocol requires a 30 per cent reduction on 1980 levels of SO_2 emissions by 1993. In Ireland's case this would impose a target for the whole economy of 157,000 tonnes, which our forecasts in Table 3.6 demonstrate will not be met on the basis of current policies.

Table 3.6: *Sulphur Dioxide Emissions (thousand tonnes)*

	1993	*2000*
Industrial	66	77
Transport	16	16
Residential	22	24
Commercial	6	6
Utilities	83	111
Total	192	234

Strategies for meeting this obligation include the use of low sulphur fuels, more use of natural gas (a sulphur free fuel) or the installation of desulphurisation equipment at power plants. McCoy (1991) examined the macroeconomic impact of this obligation for Ireland. He suggests that the costs of meeting this objective may not prove to be too substantial for the economy if gas consumption can be expanded significantly. However, future commitments need to be carefully considered.

The Sofia Protocol on NOx emissions called for stabilisation of 1995 emissions at 1987 levels. Ireland would be extremely unlikely to meet such a target, see Table 3.7.

Table 3.7: *Nitrogen Oxide (NOx) Emissions (thousand tonnes)*

	1991	*2000*
Industrial	19	31
Transport	85	91
Residential	7	10
Commercial	4	5
Utilities	47	67
Total	162	204

In terms of carbon dioxide emissions the Rio Earth Summit of 1992 failed to agree on a binding climate change convention that contained firm targets. However, the EC have proposed targets in a community strategy to limit CO_2 emissions and to improve energy efficiency. The target set is the stabilisation of Community CO_2 emissions at the 1990 levels by the year 2000. As part of that strategy the Commission proposed a combined tax on carbon and energy. Some member states, including Ireland, seek a concession to increase their 1990 levels in order to pursue economic convergence. However, our forecasts suggest that Irish emissions by 2000, even allowing for significant structural changes, will be over 20 per cent above the 1990 target level, see Table 3.8.

The influential Intergovernmental Panel on Climate Change (IPCC) have reported that reductions of about 60 per cent on current emissions would be required to avert serious problems due to the greenhouse effect. If a constraint of this severity was put on the energy sector the necessary structural changes would be enormous.

Carbon taxes of the magnitude proposed by the EC, the introduction of which is now conditional on other industrial blocks taking similar measures, were shown by Fitz Gerald and McCoy (1992) to be of limited value in reducing CO_2 emissions. However, they did find evidence of the presence of a "double dividend" for Ireland in such a tax. The dividends are improved environmental conditions and higher output and employment. This productive efficiency gain results from the shifting of the tax base from labour to energy; the demand for energy is inelastic whereas the demand for labour is relatively elastic. The result is an overall improvement in the competitiveness of the tradable sector.

Table 3.8: *Carbon Dioxide Emissions (million tonnes)*

	1991	*2000*
Industrial	5.16	6.79
Transport	6.24	6.66
Residential	5.92	6.72
Commercial	2.02	2.34
Utilities	10.94	15.25
Total	30.28	37.75

Incorporating environmental constraints into energy policy has significant implications for policy makers. In the first instance, the presence of large and potentially serious environmental externalities associated with energy use can provide a legitimate reason for intervening in a free market. In the absence of intervention the full social costs, private plus external, of energy use will not be taken into account and this will result in too high a level of energy use. Even given the uncertainty that surrounds environmental issues like global warming, policy makers can be justified in taking a "precautionary approach" in controlling energy use. The form of control used can be based on either regulations and standards or a market based approach of taxes and/or tradable permits. Economic theory would come down strongly in favour of the latter approach on the grounds of efficiency, yet there is a predominance of direct regulation in dealing with pollution matters which "reflects the bias toward the use of the tools of law enforcement and technical fix to achieve government ends" (Shortle, 1992).

In intervening in the energy market on environmental grounds policy-makers must still decide on what is the socially desirable level of energy use. This is a Herculean task given that the policy-maker may have no better information than the market participants. Satisfying the environmental constraint may also lead the policy-maker into conflict with other goals, like the social obligations to employment in the peat industry. When concerned about global or international environmental issues, domestic policy-makers should consider possibilities of better and cheaper solutions by financing clean-up activities in other countries. McCoy (1991) showed that, in terms of Irish macroeconomic performance, the government would have achieved a better result for the Irish economy and the European acid rain problem by helping finance the installation of desulphurisation equipment in Eastern Europe than undertaking the same clean-up domestically.

6. Competition and Ownership

The EC Commission proposals are designed to promote energy efficiency by opening up the EC market and increasing competition. Their emphasis is rather different from that of the energy reforms of the UK in the 1980s where the crucial question was that of ownership. The EC Commission proposals do not deal directly with the issue of ownership but, by attempting to free trade in electricity and gas, they aim to increase competition.

The problems posed by concentration on the issues of ownership have been highlighted by Helm (1991). The constraints placed on the reorganisation of the UK electricity industry meant that a duopoly situation was created replacing the previous monopoly, with only a limited increase in competition. The resulting system depends heavily on regulation to ensure that the system runs efficiently in the sense of minimising the economic rents arising from the structure of ownership.

As outlined above, the EC Commission proposals involve the separation of the generation, transmission, and distribution of electricity to increase transparency in pricing electricity and gas supplies. These proposals recognise that the transmission of electricity and gas is normally a natural monopoly. However, it is quite possible to have competition in generation and competition between major consumers or distributors. It is hoped that by increasing transparency and allowing increased competition in generation and distribution, that efficiency can be increased.

Already there are pressures at a European level for increased freedom to trade energy. This issue has arisen in the case of Germany where major industrial consumers of expensive German electricity want the right to import cheap electricity from France or the Netherlands (European Parliament, 1992). If the new regime were introduced it would pose major problems for the current German policy of burning expensive domestic coal and would require considerable changes in the German electricity system.

The introduction of such a regime at an EC level has major implications not just for the electricity and gas utilities but also for other suppliers of fuel. Increased competition from abroad or from the liberalisation of the domestic generation systems will put major pressures on the domestic suppliers of high cost primary energy: coal in Germany and the UK, peat in Ireland. The implications of this policy for the British coal industry became apparent in 1993 with the closure of the majority of the remaining pits, raising a major political storm. It also raises the question as to whether the pricing of electricity from nuclear fuel takes full account of the clean-up costs associated with its decommissioning.

The effect of increased competition will be to highlight the areas where domestic regulations or hidden subsidies give rise to increased costs and a loss of competitiveness. For Ireland, successive reports, Convery, Scott and McCarthy

(1983), DKM (1991), and the Report of the Industrial Policy Review Group (1992) have highlighted the need for transparency in pricing to deal with the most obvious sources of increased domestic costs. In allowing new entry into generation and permitting large consumers to shop around, the excess cost burden of peat electricity generation will be highlighted and there will be strong pressures to phase out plant. While Chapter 5 shows that the cost penalty of peat fired generation is aggravated by the high level of indebtedness of Bord na Móna, which represents a sunk cost, the possibility of future competition and environmental regulation makes any new peat fired plant unattractive.

There are a number of possible benefits which may result from a successful introduction of competition into certain sectors of the energy industry: it may result in lower prices, exerting a strong influence on costs - a potentially serious problem in a state owned monopoly; it may also exert pressure on public policy to increase transparency and improve decision making. While the potential benefits are obvious, however, it is not as clear how effective competition can be implemented. This Chapter considers the areas of gas and electricity, the areas covered by the draft EC directives. The DKM report to the Industrial Policy Review Group (DKM, 1991) dealt with the problems of lack of competition in the oil distribution market.

It is extremely difficult to establish the extent to which the current unregulated monopoly position of the ESB and BGE have resulted in economic inefficiency. In both cases the very existence of a monopoly reflects the importance of increasing returns to scale: competition in electricity or gas transmission would be extremely inefficient. However, they both face competition from other fuels; this is particularly important for gas. It is only in certain areas of each business that competition within the sector (e.g., electricity generation) is feasible. However, the absence of explicit regulation of any monopoly must be a cause for concern.

One possible area where one might expect problems is that some of the potential monopoly rent may accrue to the employees as higher pay or higher staffing than would be possible in a competitive position. Figure 3.7 looks at relative average labour costs for the utility sector in Ireland and other EC Countries. In this case average labour costs in utilities are compared with those in manufacturing in each country. In every case costs are higher in utilities, possibly due to the high average skill level of those employed. However, it may also be attributable to the monopoly nature of the utility sector in the countries examined.[9] These data do not suggest that employees in Irish utilities in 1988 enjoyed a markedly more favourable situation than those in other EC countries. In the case of the gas industry, the extensive use of sub contracting goes a long way towards ensuring that such rents are competed away.

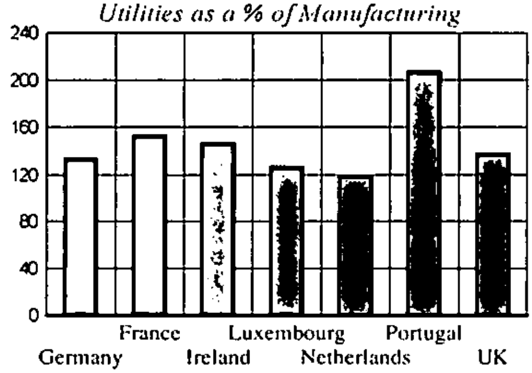
[9] The data are for 1988, before the major changes in the UK could affect the situation there.

In the electricity generation sector developments in technology and changing market structure have meant a major reduction in staffing levels in new plants abroad compared with current Irish practice. The opening up of the management of generation stations to competition could provide an impetus to increase efficiency in this area of the industry.

Figure 3.7

Relative Labour Costs

Utilities as a % of Manufacturing



Source: EUROSTAT: *Labour Costs Survey*, 1988

The numbers employed relative to output in the Irish utilities do appear high *vis-à-vis* our neighbours. However, direct comparison is difficult because of differences in coverage (treatment of retailing, etc.) and because of the very dispersed nature of the Irish population served by the transmission system.

The argument for separating transmission from distribution in the gas system throughout the EC is potentially important for Ireland. With the construction of a gas interconnector to the British gas grid we will become dependent on that system for a significant share of our energy towards the end of the decade. This dependence on a single British pipeline could leave the Irish system vulnerable to monopolistic behaviour by the owner of the British gas grid. The EC directive, by regulating the transmission system in the UK, and elsewhere in the EC, would help protect the Irish economy from such predatory behaviour. The changes within the UK gas system have already implemented some of the crucial features of the EC approach.

It is also important for competition, not only in gas but also in electricity, that the running of the gas interconnector, and also the domestic transmission system, should be strictly regulated. It should be open to third parties, such as the ESB or independent electricity generators, to buy gas elsewhere and to ship it through the pipeline, paying only the transmission costs. Without this access for third parties, competition in gas fired electricity generation will not be possible.

In electricity there are two major possibilities for increased competition arising out of the EC directives. First, there is the possibility of new entrants domestically into the electricity generation business. Secondly, there is the possibility of competition from outside the Republic through new interconnectors between the electricity system in the Republic and the rest of the EC.

The scope for increased competition within the domestic system is limited by the scale of the system. In the United Kingdom, for example, it is possible to have many generation stations which will compete to supply power to the system. Since the system was deregulated there has been a very big increase in the number of gas powered stations built to compete for business, the so called "dash for gas". In the system in the Republic, by contrast, where there are effectively only 15 significant thermal stations, the scope for competition is much more limited. The size distribution of stations is shown in Table 3.9. This shows that one station, Moneypoint, accounts for over 40 per cent of the power produced. This station is also significantly cheaper than any other as it burns coal.

Table 3.9: *Size Distribution of Thermal Electricity Generating Stations, 1991*

Size of Plants, Units Sent Out, Millions	*Number*	*Millions of Units Sent Out*	*Per Cent of Total Sent Out*
Less than or equal to 250	7	963	7.4
Greater than 250 - Less than 1000	4	2106	16.1
Greater than 1000 - Less than 2000	3	4586	35.1
Greater than 2000 - Less than 10,000	1	5393	41.3

Source: ESB Annual Report, 1991

In any competitive system where all individual plants competed for business the dominance of Moneypoint would remain and, given the technology and relative fuel prices, all the power it produced would still be bought by the system. If the owners of a private Moneypoint were paid the existing marginal price for electricity then substantial profits would be obtainable.

The next three biggest stations account for 35 per cent of the power generated. These stations each have an installed generating capacity of around 500 MW. Thus in the existing scheme four stations account for over three-quarters of the power produced in the system.

While the structure of the system and the scale of operation of the four major plants would make competition difficult at present, the need to expand the system, discussed above, does leave scope for new entrants to construct additional plant to compete for business. Changing technology means that somewhat smaller gas fired plant, with a capacity of around 250 MW or less, could be economic, representing a scale of investment which might be attractive to independent operators.

A feature of the current system is that the largest four stations, accounting for over three-quarters of electricity generated, are generally the most efficient generators on the system[10]. The smaller plant, with two exceptions, are peat fired, with production costs well above those for all other stations. The effect of competition with new entrants would initially be to squeeze out the smaller less efficient plants. Effectively competition, with no other restrictions, would involve a phasing out of peat fired stations. Probably the major initial savings would occur from this restructuring rather than from competition *per se*.

The advent of competition would force a choice to be made on whether to provide an explicit subsidy for peat fired electricity generation stations or to close them. As discussed in Chapter 5, a substantial part of the excess costs of existing peat stations is due to the high debt of Bord na Móna resulting from unprofitable investment decisions in the past. If it were decided to phase out the peat stations gradually and if Bord na Móna were relieved of the debt, which is in any event state guaranteed, they would be in a better position to compete. However, if they were to survive they would still require a subsidy.

The issue of competition is intimately related to the connection of the electricity and gas systems of the Republic to those of the rest of the EC. The most likely way in which competition could be introduced will be through a combination of the restructuring of the ESB to separate out generation, currently under way, and the construction of one or two new gas fired stations. The scale and capital cost of such plant would be more feasible for private operators than in the case of large coal fired stations. In addition, the environmental problems associated with coal would make coal-fired stations an unattractive and risky form of investment.

With the domestic supply of gas due to run out at the end of the decade any new gas fired plant will be dependent on the gas interconnector to the UK. This will present a limitation on the scope for new investment in gas for security reasons. Currently around 25 per cent of electricity is generated from gas. While up to 50 per cent was generated from gas in the early 1980s, it would be dangerous in the future to rely on a single pipeline for the fuel needed for much more than, say, a third of normal electricity supplies. Any accident which affected the pipeline could cause massive economic disruption. This limits the scope for new stations dependent on gas to provide competition.

The restoration of an electricity interconnector to Northern Ireland could provide a number of advantages including an increase in scope for competition. The cost of such an interconnector is relatively small compared to that for an interconnector to the UK. The restoration of the existing line in purely economic terms would cost under £1 million while an interconnector to Britain would cost

[10] Only one of the smaller stations has a unit cost lower than one of the top four stations.

between £250 million and £500 million. Even if security requirements were to raise the cost of reopening the Northern link it would still provide scope for increasing competition and reducing costs of electricity throughout the island.

In recent years the cost of electricity has been significantly higher in Northern Ireland than in the Republic. The Northern system depends on two stations for over 80 per cent of power supplies, these two stations burning oil and coal. If the problems with the security of the interconnector could be overcome, the increase in the scale of the island system and the complementarity of the two existing systems could provide substantial scope for increased efficiency and reduction in costs, even before the issue of competition is considered. In the long term it would be desirable on the grounds of economic efficiency to move towards an integrated transmission system for the island.

As an integrated system it is likely that some marginal power plants which provide reserves for the existing systems could be closed. The need to keep plant on standby in the two systems simultaneously would be eliminated. Scott (1980) estimated that significant savings could be made from these changes alone. In addition, the larger scale of the system would provide increased scope for competition between generation stations. It would also allow a greater use of gas, the fuel currently favoured in the UK by independent power producers, without raising the integrated system's dependence on that fuel to insecure levels. In addition, a shift to greater use of gas throughout the island would have environmental benefits.

The possibility of connecting the existing electricity system in the Republic to the UK system also provides scope for increasing competition and could potentially provide a number of other benefits allowing a more efficient use of the existing system. However, the cost of the interconnector, a minimum of £250 million, is a high price to pay for these benefits. If the sole purpose of the interconnector to the UK were to provide additional capacity to the system then that objective could be met more cheaply by building a new domestic power station, whoever owned it. As outlined above, the current cost of electricity in the Republic is fairly close to that in the UK. In so far as cheaper electricity were available through the interconnector, it would only be because of the overheads carried by the ESB system due to the continuing use of peat. Unlike the situation in Northern Ireland, it would appear that the interconnector to the UK would not be justified to supply base load.

An interconnector to the British system would confer other benefits by allowing a reduction in reserves in the system in the Republic and through the potential for direct imports to provide the possibility for some increase in competition. At present it seems unlikely that these potential benefits from the interconnector to Britain would justify its high cost. The desire to increase competition within the system may best be served initially through developing the system along the lines suggested in the EC draft directives and through seeking to integrate the system within the island.

While the small scale of the domestic electricity system does not prevent the introduction of competition in generation, it will make the terms under which such competition is introduced rather complex. Buying electricity in bulk is not something which can be done on the spur of the moment. Before independent suppliers are prepared to risk an initial investment of £100 million or more they must be assured that the terms on which the electricity will be purchased will be fair. However, if competition is to have any meaning there must remain some uncertainty as to whether the electricity will be bought and whether the investment will succeed; otherwise there will be no incentive for the managers of the new plant to minimise the price charged. Balancing this uncertainty against the riskiness of the investment will prove difficult.

In addition, the importance of security of supply means that the reliability of the potential supplier will have to be assured. In planning future capacity account will have to be taken of the potential new suppliers. Some regulation of the development of new capacity may also be required. If a number of independent contractors simultaneously decide to invest there could be wasteful duplication and the new investment could even exceed the potential for gas supply.

On the other hand, if the new contractors fail to deliver on promises it could pose major problems at a future date. The state could be left short of electricity because a contractor failed to deliver on time or it could be left bailing out an unsatisfactory private investor because the economy could not afford failure. The complexity of the contractual arrangements in the UK highlight the difficulties in actually implementing a competitive environment. The more regulation is necessary the more artificial, and possibly ineffective, the competition. Given the scale of the electricity industry relative to the Irish system such problems are unavoidable.

The EC directives are generally pushing in the direction which Ireland would wish to travel. At a national level there is an interest in free trade in gas. In the area of electricity the EC proposals may be less effective because of the costs of integrating the Irish system into the EC grid. However, there is a strong case for encouraging the development of competition in generation within the island as a whole.

The framework which would allow competition in generation to develop is currently being implemented. This involves the separation of generation from transmission in the Irish system and the establishment of a clear set of rules for purchasing electricity from private suppliers. The extent of such competition could be increased by selling some of the smaller plants to private operators or, alternatively, sub-contracting their management to new operators. However, privatisation of the essential monopoly elements of the system, such as transmission, would do nothing to increase competition and would necessitate a heavy burden of additional regulation. These monopoly elements include transmission, the local distribution network and the generating stations without which the system could not function.[11]

An important non-energy argument frequently put forward for privatisation is that the proceeds can be used to reduce the national debt. While there may be good grounds for privatising some assets to promote competition and efficiency this particular argument is fallacious. It ignores the fact that, when sold, the state's assets will fall by an amount equal to the reduction in its debt leaving no change in its net liabilities. It is only if the asset can be expected to produce higher returns to the nation in private hands that the sale will benefit the country. On a priori grounds this can be expected to happen where the enterprise is operating in a competitive environment.

The move to competition in generation has strong implications for the peat industry. It makes the construction of any new plant unattractive. Existing plant could continue in operation to the end of its useful life if Bord na Móna were relieved of the burden of state guaranteed debt and the benefit passed on in lower fuel prices to the generation sector. Otherwise it is likely in a competitive environment that they would be phased out in favour of other more competitive stations. The social implications of this issue are dealt with in the conclusions.

7. Pricing and Taxation

Pricing

The burden of the high cost of provision of public services, including the services of the public energy utilities, posed major problems for the tradable sector of the economy in the first half of the 1980s. Since then changes within the economy generally, and increased efficiency within the energy sector itself, have served to reduce the excess burden suffered by the tradable sector. For the future the challenge is to achieve significant further increases in efficiency. However, even with increased efficiency, because of the isolated nature of the domestic energy system, Ireland may face higher energy costs over the 1990s than our EC neighbours. What should be done about this?

Just because the cost of one of the inputs into the productive sector of the economy, energy, may be higher than in other EC countries does not justify subsidising that factor, either directly or indirectly.[12] To the extent that the price difference might represent inefficiency it should be tackled by reorganising the sector. However, if it represents a necessary feature of the isolated nature of the Irish economy it would still be inappropriate to offer a subsidy to equalise costs.

If Ireland does not have a comparative advantage in energy production then a subsidy will only distort decisions by the productive sector leading to a

[11] For example, Moneypoint station is so central to the system that the owners of that station (and the employees) will still have huge leverage, however ownership is structured.

[12] One indirect subsidy would be to grant aid energy investment under the EC Structural Funds. This would reduce the financing costs of the utilities.

misallocation of resources. The fact that energy costs are frequently considered important to industry[13] should not disguise the fact that they are only one of a wide range of factors which contribute to costs and competitiveness. All subsidies have to be paid for.[14] For Ireland energy is predominantly an imported factor of production which has significant negative externalities for the environment. If a policy of subsidisation of energy for industry were adopted this would encourage industry to consume additional amounts of energy over and above the efficient level, giving rise to additional pollution.[15] It would also encourage the productive sector to substitute energy for other factors, including labour, at the margin. Thus it would be inappropriate to devote resources to subsidising energy prices when the same resources could be used, for example, to reduce taxes on labour.

In addition to charging the full private cost of energy to consumers, both commercial and domestic, there is a strong argument for charging for the negative environmental externality associated with consumption of fossil fuels. The pollution, to which consumption of such fuels gives rise, leads to problems like acid rain and contributes to the process of global warming. This issue has been discussed in detail in two ESRI papers, see Scott (1992) and Fitz Gerald and McCoy (1992). Where the externality affects the country as a whole, or spreads beyond its borders affecting other EC members, the appropriate instrument to use to ensure that the polluter pays the external costs is a tax. Regulation may be more appropriate where the pollution only affects a limited geographical area or where even very small emissions are likely to be harmful (dioxins and plutonium). An example of this was the imposition of controls on burning of solid fuels in Dublin.

More complex issues arise in determining the appropriate price to charge different users of a particular form of energy. For example, how should the allocation of overheads be made over the household and the commercial sectors when determining electricity prices? In principle each sector should pay the full economic cost for what they consume. However, this is often difficult to determine. In addition, there is significant cross-subsidisation of energy users in one region or sector by users in other regions or sectors.

In general, users of electricity in rural areas pay substantially less than the full economic cost for the provision of necessary services. In Ireland, as in most other countries, it is considered appropriate not to have significant differentiation in regional tariffs. As a result, the costs associated with the dispersed nature of the Irish population fall on users throughout the system. Generally, if the

[13] In 1989 energy costs accounted for 1.8 per cent of the value of gross output of transportable goods industries and 4.1 per cent of net output.

[14] The opportunity cost of EC funds is not zero. It is identical to the cost of funds to the Irish government - the rate of interest it pays on foreign debt.

[15] The fact that the elasticity of demand for energy is low may mean that the short-term effects from distorting the price may be low. However, in the longer term the elasticity of demand is likely to be considerably higher.

competitiveness of the economy is the first priority of economic policy, it is more appropriate that these additional costs, over and above the economic cost of providing the service, should be charged to the household rather than to the commercial sector.

A final issue on pricing is the treatment of the natural gas supplies which are available off the South coast. The Irish government gas distribution company BGE has the right to buy all this gas at a very low price. Since this gas find began to be exploited in the 1970s a substantial part of the gas was supplied at lower than the market price to the state owned fertiliser company NET. This represented an inefficient use of a scarce resource. As has long been apparent, with the prospect that these resources will be exhausted by the end of the decade, the appropriate opportunity cost for this gas is the price of the gas which will be imported in the future through the gas interconnector (McDowell, 1992). This price, appropriately discounted, should provide the floor price for gas sales to all users in the Irish energy market.

The position changed somewhat on the sale of the fertiliser plant to a new company IFI. NET still receives the gas at a low price from BGE but it then sells the gas to IFI at what is stated to be a market price. The profit it makes on the deal is used to pay the interest on its debts which are, in turn, guaranteed by the state. Assuming that the price charged to IFI is the market price, related to the likely price of gas supplied through the interconnector when it comes on stream, this involves no distortion of the market. If NET were closed, its debts would become part of the national debt and the higher dividend which BGE would pay as a result of the sale of gas directly to IFI would go to offset the higher interest payments.

Subsidies and taxes

Taxes and subsidies affect the price of energy in a range of different ways. In some cases they may even have conflicting objectives. The two reasons for direct state intervention to change energy prices are:

- To raise revenue.
- To correct market imperfections or externalities.

Probably the dominant factor in determining the level of taxation on energy over the last 20 years has been the need to raise revenue. This has resulted in a range of taxes at very different rates. The taxes are very heavy on oil products, especially petrol and diesel. Other fuels, especially solid fuels, have been subjected to a much lower tax or, in the case of peat, a very substantial indirect subsidy.

Taxes on energy have a major attraction from a public finance point of view: the demand for energy is quite price inelastic so that consumption is relatively invariant with respect to the rate of taxation. This contrasts with the elasticities of demand for other factors of production, such as labour, and other products, which have much higher elasticities of demand. Fitz Gerald and McCoy (1992) show that because of this difference in observed elasticities of demand, a shift from taxes on labour to taxes on energy would be likely to increase employment and output in the economy by increasing productive efficiency. Even though Irish industry would have to pay more for energy, the bulk of the burden of energy taxation falls on the household sector. By contrast, in the case of social insurance contributions, a higher share of the incidence of this tax falls on the tradable sector of the economy.

However, the use of taxes and subsidies to correct market imperfections and externalities shows up a number of inconsistencies in approach. This inconsistency is not solely a feature of the Irish energy sector but it is also apparent in the tax and subsidy policies of other EC countries. While the heavy tax on motor fuels can be explained in terms of the negative externality of traffic congestion and pollution, the logic behind the differential taxes on other oil products, rather than on solid fuels, is not clear. Coal has a more adverse impact on the environment than does oil when burnt for heating purposes yet coal is taxed more lightly and grants were given to households in the late 1970s and early 1980s to switch to such solid fuels.

A heavy subsidy has been paid indirectly to encourage peat consumption. This has been achieved by forcing the ESB to purchase large quantities of peat for use in electricity generation. This happens in spite of the fact that the fuel is less efficient for electricity generation and in spite of the fact that it is more polluting than oil or gas. The reason for this policy is the desire to protect employment in the peat sector.

As discussed above, the move towards a free market in electricity and gas will force greater transparency in the subsidisation of peat consumption. The possible introduction of carbon taxes would make the use of peat even less attractive for the ESB.[16] Generally, there will be considerable pressures in the future to move away from peat fired electricity generation. However, this industry is an important source of employment in parts of the Irish Midlands where there is no other major employer. This parallels the situation in the UK with coal.

This approach to providing necessary employment in the Midlands is probably quite inefficient in the long run. It involves a significant on-going subsidy in the short-term and the continuation of the jobs in the long term would require a substantial increase in expenditure. A more appropriate policy would be to use the subsidy to provide alternative productive employment in the region which would come on stream as the existing plant closes down. This additional employment could be achieved through a diversification of activities by Bord na

[16] Although, as discussed in Chapter 5, it would not alter the additional cost to the nation of using peat.

Móna or through other new ventures. The aim should be to achieve sustainable employment which will continue in the future without an on-going subsidy.

8. Concluding Remarks

This Chapter has concentrated on the implications for Ireland of proposed EC directives on energy. These directives are pushing Ireland in the direction that it would probably wish to travel. There is both the possibility and the need to introduce competition into the energy and gas systems. However, this will be difficult given the small size of the energy system of the Republic. In the case of electricity, competition can best be introduced by allowing new operators to build and / or operate generating stations. The size of these generators should not be such as to dominate the system. In the case of gas, the transmission system should be open to use by third parties. It would not be desirable to privatise the elements of the energy system which are essentially natural monopolies, like the transmission network.

In the long run the energy transmission systems on this island should be fully integrated to permit proper competition. It is time to start planning an energy policy for the island. On the limited evidence available, an electricity interconnector to the UK looks like bad value for money. Competition benefits might be achieved at a lower cost by expanding domestic generation.

Given the increasing significance of environmental issues for the energy sector there is a critical and obvious need for co-ordinated development of environmental and energy policies. The result of increased competition and environmental regulation will be serious pressure on the peat industry. The subsidy to this industry should be made explicit. As this industry has poor long-term prospects but is of considerable social importance in the Midlands, strenuous efforts must be made over the remaining life of the existing plants to find alternative businesses to provide satisfactory long-term employment. Making the subsidy explicit could facilitate this process.

Users of energy should be charged the full price of energy. Competitiveness is better enhanced through measures directed at the labour market than through subsidising energy. The taxes and subsidies on energy should be reformed to reflect the environmental cost of different fuels. However, because of its low demand elasticity, it remains a suitable instrument for raising revenue for general budgetary purposes.

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Chapter 4

ENERGY CONSERVATION IN THE HOME - ARE WE CONTRARY?

Sue Scott[1]

Preface

This Chapter is about efficiency in the meeting of people's demands for warmth, motive power, cooking and the like. Provided that the consumer enjoys the same level of comfort for the same cost overall, a unit (or kilowatt hour) used is the same as a unit saved. Therefore conservation should be seen as a straight-forward alternative supply option (a negawatt) and should logically be viewed within the ambit of the internal market ideal.

1. Introduction

Recent analyses of carbon taxes have come out broadly in favour of switching taxes to energy. In general, environmental protection is best served by market-based measures and, we maintained, measures such as tax switching, from say labour to pollution, would tend to be more beneficial to society than other measures. To omit such market-based measures would be to leave in place the wrong prices - pressures which encourage people to excessive use of the environment. This is not to say that one should have no reservations about such a policy and the aim of this paper is to address some of those reservations.

Coming to the point, the main reservation is that very heavy taxes might have to be introduced in order to have any sizeable effect on demand, and that these could cause considerable disruption and hardship. For market-based measures to work successfully, there has to be a well-functioning market in the first place. This requires the fulfilment of certain important conditions which are easily

[1] The author wishes to thank F. Convery, P. Honohan, B. McSharry, P. Minogue, M. Murphy, K. O'Rourke, B. Whelan and J. Williams for their assistance.

overlooked, such as the existence of many buyers and sellers, open access, good communications, knowledgeable consumers, no uncertainty, price transparency with no hidden or omitted external costs, the appropriability of benefits, access to credit and so on. Brechling *et al.* (1991) give a fuller discussion of sources of market failure. Reservations about energy taxes amount to saying that these conditions might not prevail.

The sceptic can rightly point to the example of energy conservation in the home. Here, it is said, there have existed (whatever about today) many highly worthwhile energy saving investments which have not been taken up - proof surely of contrary behaviour on the part of consumers or a poorly functioning market. This is to some extent true and the aim of this paper is to gauge the extent and the nature of this problem.

2. Outline of Discussion

We will investigate the issue of non-takeup of energy conservation measures in the home as follows. First we ask the basic question whether there actually are worthwhile measures to be undertaken. Next we outline a household survey which we have undertaken with a view to investigating the important features of market failure. Then, using some preliminary results of the survey, we can look at households which have not installed energy saving measures and ascertain some of their characteristics. Some disentangling of influences is then attempted. Finally, with basically three broad sorts of policies available, namely exhortation and information, regulation, and price, we can start to see if our survey shows any pointers to a logical approach for policy.

3. Are Energy Conservation Measures A Good Investment?

How worthwhile are household energy conservation measures? A search for appraisals of these investments yielded the paper by Minogue (1980) covering Ireland, and a few for the UK, including Pezzey (1984), Shorrock and Henderson (1990) and the Energy Efficiency Office (1991). Some of their results are presented in Figure 4.1, where for brevity we have reported only on the conservation items covered in our survey.

There are no recent published appraisals for Ireland on general release. To our knowledge there is no published update of Minogue's seminal work, except by O'Rourke (1992) for restricted circulation. There are only summary statements about energy saving measures, published in information sheets released by EOLAS, the state sponsored board for science and technology. This scarcity of information is in itself interesting. In the intervening years since Minogue's work, though the Gulf War gave us a scare, real energy prices have collapsed. To counter this, the real price of conservation technology might also have come down. However at current very low real energy prices and high interest rates, doubt must surround the net benefits today of some of the conservation measures presented here. It comes as a surprise therefore to see from O'Rourke's and more recently McSharry's (1993) preliminary figures that a number of conservation measures are still highly worthwhile to the householder today. These are the sets of figures in the columns headed (5) and (6) in Figure 4.1. In addition it is notable how consistent the figures are with those from the UK and from other years. This then does establish that it is a paradox that people have not installed these worthwhile measures. They have seemingly chosen to spend more rather than less money on their comfort levels. If environmental external costs are added to the price charged for energy, the net benefits of conservation measures would be further enhanced.

4. The Household Survey

We undertook a survey of households in November 1992 which yielded 1,208 completed questionnaires. The aim of the survey was to find out what conservation measures respondents had or had not installed and whether they considered that these measures would save money in the long run. Respondents were asked to state what their priority item would be if they had money to spend on energy conservation. We explored the reasons for not installing items, trying to establish, for example, the presence of plain financial constraints ("I have more urgent spending priorities"), lack of motivation owing to low price ("my energy bill is quite small anyway"), hidden costs ("I do not want the mess or hassle"), lack of access to loans ("it is hard to find the cash or credit") and informational problems ("it is hard to find the time to find out about it"). On the last point about information, we also asked householders what sources of information on energy conservation they used, such as ENFO, the environmental information agency, or radio.

The guiding principle behind the formulation of questions was to investigate the extent to which conditions for a well-functioning market were satisfied. With a clearer understanding of the barriers, be they lack of knowledge, information or access to credit, or perceived hidden costs and the like, policy action if deemed necessary can be better directed. Another potential barrier to rational investment arises when investors reckon that they will be unable to reap the benefits of their investment - i.e. non-appropriability. This can occur if the householder is about to move house or rents the house, though in the latter case it might still be worthwhile for landlord and tenant to negotiate on the investment, or perhaps even for the tenant to proceed anyway if the savings on the fuel bills justify the outlay. Indeed, questions included tenure as well as the type and age of their housing, whether they had central heating, and what main fuel they used for space heating and for water heating.

Figure 4.1: *Investment Appraisals of Energy Conservation Items*[2]

	1	2	3	4		5		6			
	Ireland, 1979	*UK, 1984*	*UK, 1990*	*UK, 1991*		*Ireland, 1992*		*Ireland, 1993*			
	IRR[3] %	*(NPV/K)*[4]	*a good investment*	*Cost* £	*Payback Years*	*Cost* £	*Payback Years*	*Cost* £	*NPV*[6] £	*Life Years*	*Payback Years*
Lagging Jacket	77 - 135[5]	16-51	up to 80mm (from<50mm)	5 - 8	0.5	6-8	0.3	10	322	10	0.3
Attic Insulation	13-28 (50mm) 16-52[5]	1-9 (100mm)	up to 150mm (from<=25mm)	170 - 280 120 - 145[5]	3-4 2	100-150	3	200	566	20	3
Draught Proofing	0-32 9-32[5]	0 to 2.4		110 - 190 40 - 5[5]	3-10 1-3	20-150	2	150	218	12+	4
Insulating Curtains						0-100	4				
Cavity Wall - Block Insulation	9-19	1-5	for 80% of all cavity walls	300 - 400	4-6	500-1500 (Cavity Wall and Dry Lining)	3-15				
Dry Lining of Walls	0-5			1500-3000 180-225[5]	20+ 2-4						
Low Energy Light Bulbs[7,8]			if in fairly continuous use			15	1-2	15	30	3.6	1.2
Double Glazing	neg-2 (secondary windows)	-.7 to -.2	if replacing anyway	150-530 120-280[5]	8-10[9] 4-10[7]	500-3000	5-50				

2. It is important to bear in mind the assumptions associated with these measures, used by the sources: (1) Minogue, 1979, (2) Pezzey, 1984, summarised in Brechling and Smith(1992), (3) Shorrock and Henderson, 1990, (4) Energy efficiency Office, 1991, (5) O'Rourke, 1992, and (6) McSharry, 1993.

3. IRR = real internal rate of return; values above 5 indicate a good investment.

4. NPV/K = net present value / capital cost, a positive value indicates a good investment, showing how many times you get your money back.

5. DIY, that is do-it-yourself installation

6. NPV = net present value of the savings net of costs of the investment. A positive figure indicates a good investment.

7. per item.

8. NPV calculated by McSharry assumes use of 6 hours per day.

9. If replacing window anyway.

In addition we were fortunate in being able to ally this survey with the TEAGASC/ESRI Consumer Survey, which is a nationally representative random sample of households, stratified by area, drawn from the electoral register. This enabled us to obtain other relevant facts about our households including their net income, the level of education completed by the head of household, their occupational status, employment status, age and the numbers of people attached to the household. The questionnaire for our Energy Conservation Survey and the questionnaire for the Consumer Survey are available on request.

With limited space on the questionnaire, we concentrated on only eight energy conservation items in the home. These are lagging jacket on the hot water tank, insulation in the attic, draught-stripping of windows and/or doors, thermal or metallic insulating curtains, cavity and hollow block wall insulation, dry lining of walls, low energy light bulbs and double glazing. Ideally many other items could have been included, such as storm porches and double outside doors, meters and controls. In fact the effectiveness of many items is often governed by the manner in which they are used, which is why our question:

"how energy conscious would you consider yourself?"

included a prompt:

"e.g. adjusting time switches.."

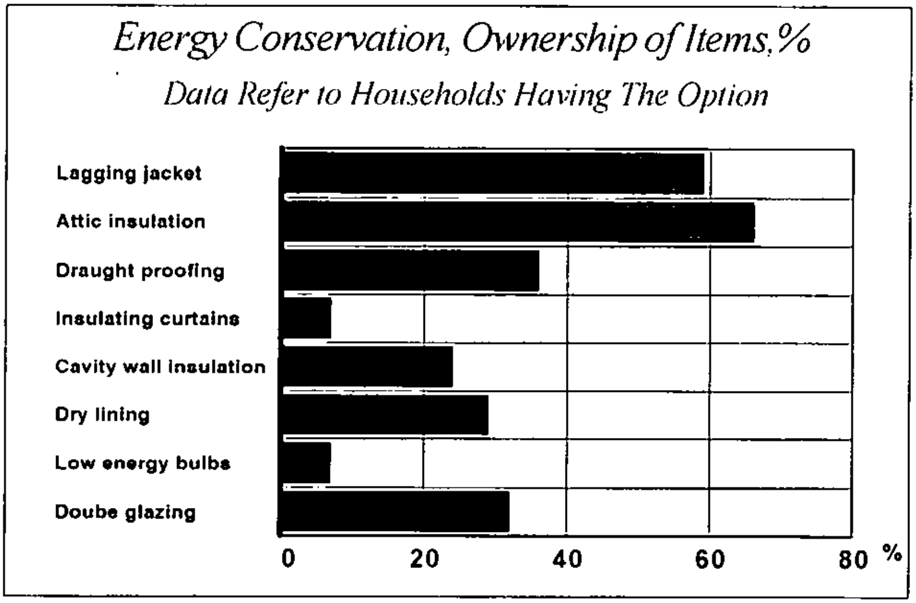
Interviewers were asked not to encourage respondents too hard to avoid saying "don't know". Unlike in most surveys, absence of opinion here could indicate lack of information or understanding which is one of our objects of investigation.

The survey response is satisfactorily representative in terms of fuels used, accommodation type, date built and tenure, age of head of household, occupation, level of education completed and income. Over-representation of urban compared to rural households necessitated reweighting of the results. Households with one person are under-represented, a common problem with surveys, to be borne in mind when interpreting the results.

5. Some Survey Results On Take-Up Of Energy Conservation

An overall indicator of ownership of energy conservation measures is given in Figure 4.2 below. The only items which appear to have been installed in over half of the houses where the option is available are lagging of tanks and attic insulation. Houses with no hot water cylinder to lag, flats and bedsits which would tend not to have attics, and houses built with solid or insulated cavity walls have been excluded from the calculation for the relevant category, because they would not have had the option. In fact the proportion of households having cavity wall or hollow block insulation is not a firm figure as respondents are frequently unsure about it. It should also be noted that the interviewers were instructed to report that a conservation item should be recorded as present if the respondent had any of it. Consequently some respondents may have only minimal loft insulation or a disintegrating lagging jacket.

Figure 4.2



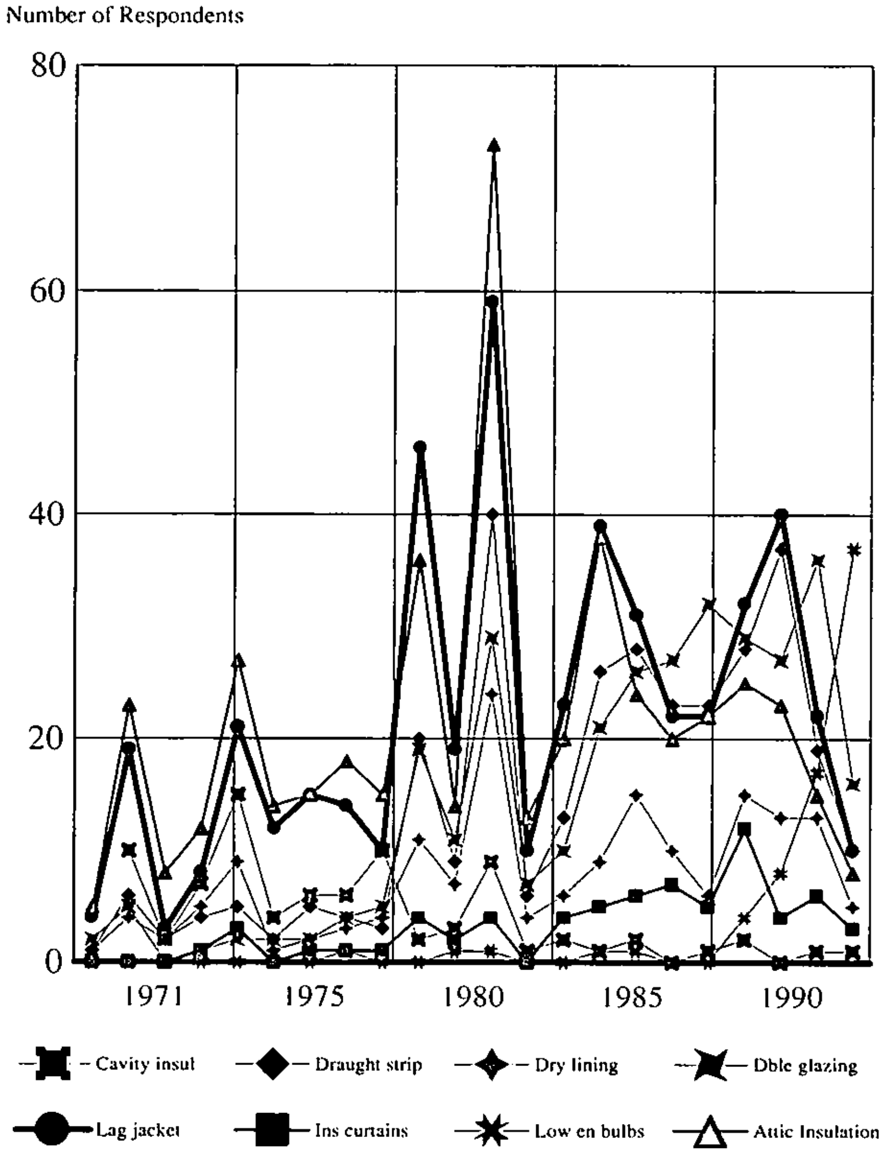
We can compare these ownership rates with those in the UK, for example. There in 1986, tank lagging and loft insulation was practically total, at 85 per cent or over (Smith, 1992). Similarly draught-proofing was nearly 20 per cent higher in the UK.

However Ireland does seem to have witnessed an improvement over the last seven years. The Foras Forbartha (1988) survey of 1985/6 indicates, for example, 49 per cent ownership of lagging jackets compared to today's 59 per cent, 52 per cent for attic insulation compared to today's 66 per cent and 10 per cent for double glazing compared to today's 32 per cent.

In fact our survey asked people in what year they installed their energy saving items. The years of installation are shown in Figure 4.3 below for each item. We must allow for the fact that the further back in time, the more the figures will be reduced by the possibility that people were not living in their present house. There is still a clear pattern of increased insulation activity after the energy price rises. The intriguing anticipation in 1972 of the OPEC price hike in 1973 is actually due to the tendency of respondents to round off in decades, saying "20 years ago", and the same applies to 1982.

Figure 4.3

Year of Installation of Conservation Items



The pattern bears out our findings that price has a discernible effect, but generally after a time lag (Conniffe and Scott 1990, Scott 1991 and 1980). However the peak of attic insulation in 1982 must also be partly due to the Department of the Environment's attic insulation scheme of 1980 to 1982, in which 29,000 attics were insulated at a cost of £1.27 millions. Also, the pattern for recent years bears witness to the mid-1980s home improvement grants, increased advertising of double glazing and promotion by the Electricity Supply Board (ESB) of items such as lagging jackets and low energy light bulbs in its attempts to restrain electricity demand.

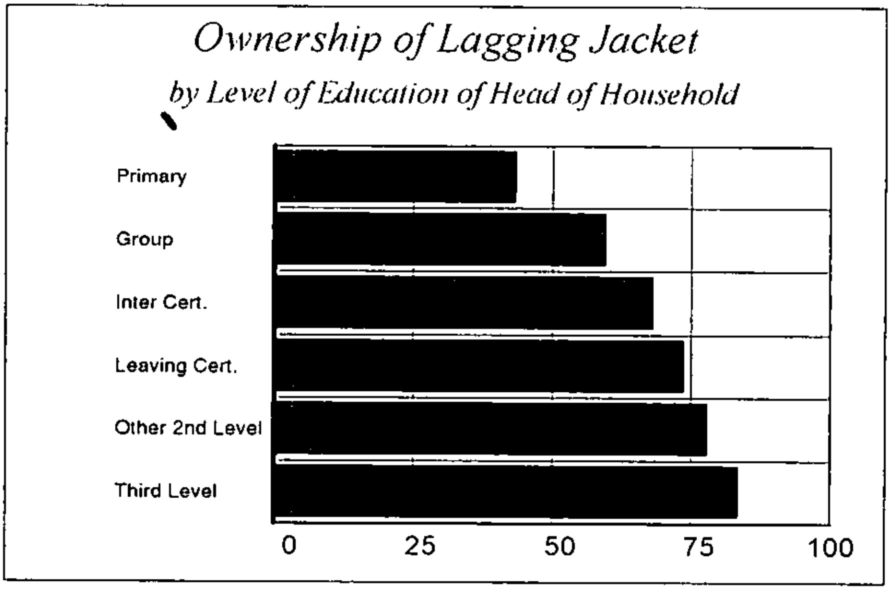
Who are the people who do not have energy saving items in the home? For brevity we will concentrate on the households which do not have the first two items on the list, which are also the most worthwhile, that is lagging jackets and attic insulation.

Households which do not have lagging jackets and those that do not have attic insulation, the NOs, are generally similar as one would expect. Looking first at the household categories which form a high proportion of the NOs compared to their proportion of the YESes, they are pensioners, people in the higher age brackets, people with only primary education completed, farmers and the unskilled, in the lower income groups, live in houses built before 1918, have no central heating, use mainly coal for space-heating in winter and rent from local authorities or own their houses outright. The last category is in marked contrast to people in houses which are owned with a mortgage who form a much lower proportion of the NOs than of the population at large. This may be because people with a mortgage have to think constructively in investment terms and already have gone through the procedure for accessing loans. Proportions apart, categories which have the largest absolute numbers of NOs are the middle age groups in full time employment and in middle income groups - understandably, as these also form the largest section of the population.

It is also useful to know within which household categories there is a high proportion of NOs, because these may be easy to target. We find that approaching half of pensioners have no lagging jacket or attic insulation. With the unemployed, over a half do not have lagging jackets whereas well under a half do not have attic insulation. A half or so of the over 60 year-olds are NOs, for each of the two items. Some two-thirds of farmers, of unskilled manual workers, of people below average income and of people who only completed primary education have no lagging jacket, and some half of these have no attic insulation. The relationship with education, which has a close correspondence with income level, is striking as Figure 4.4 shows.

Two-thirds of Local Authority tenants do not have a lagging jacket and one half claim to have no attic insulation. However, it may be difficult for them to know if they have attic insulation, which incidentally became standard in new Local Authority houses from 1975. For households below average income the proportions are about 60 per cent with no lagging jacket and 40 per cent with no attic insulation.

Figure 4.4



Reasons selected for not having energy conservation items are shown in Figure 4.5. Respondents were asked to state whether each reason applied or not, so they could select a number of reasons.

Figure 4.5: *Reasons for not having energy conserving items*

Reasons:	*% of respondents*
1. I have more urgent spending priorities	59.0
2. It is difficult to find the cash or credit	49.8
3. The household financial situation is too insecure	34.2
4. It is difficult to get round to it	29.4
5. It would not reduce my energy consumption enough	28.0
6. I do not want the mess or hassle	26.5
7. My energy bill is quite small anyway	23.1
8. It is hard to find a reliable outfit to do it	13.9
9. It is hard to find the time to find out about it	13.5
10. Warm enough	1.8
11. Want heat for the hot press	1.2
12. Need to consume a minimum to avail of gas discount	0.9
13. Waiting for period of cheap gas to expire	0.8
14. Other reasons	3.5

Looking at the reasons which apply according to our respondents, it is not surprising that the financial reasons feature strongly, that is the first three. For those below the average income who had no attic insulation, 70 per cent say it is difficult to find the cash or credit. Perceived poor return (reason 5 "not reduce energy consumption enough") and non-monetary costs (reasons 4 and 6, "difficult to get round to it", "mess and hassle") are also important for over a quarter of households. Less than a quarter would cite small energy bill (reason 7). Finding out about it or finding a reliable outfit do not apply for very many (8 and 9). Those who are also under-motivated due to cheap gas at present in fact only number 9 respondents, though this is 4 per cent of gas customers, and those waiting expiry of cheap gas number 11. It should be noted that these responses in Figure 4.5 apply to all households and not just to those who have no lagging jacket or attic insulation. Further selective analyses are proceeding but, broadly speaking, the reasons selected fall into two dominant categories. The first is financial, which given the savings forgone, indicates a failure in capital markets, that is people are not investing because they would have difficulty in getting credit. The second is non-monetary but covers aspects which are not costless, such as time and effort. Lack of knowledge of the extent of potential savings, which we saw are surprisingly large, is probably included in both these categories.

In reply to the question about which item would they choose as their top priority if they had money to spend on improving energy conservation in their home, the following ordering was given, shown in Figure 4.6, which again applies to all respondents.

Figure 4.6: *Top priority energy conservation item*

	% of households
Double glazing	46.7
Attic insulation	10.3
Low energy light bulbs	5.7
Draught stripped windows/doors	5.4
Dry lining of walls	5.3
Lagging jacket	4.0
Cavity/hollow block wall insulation	3.7
Insulating curtains	2.0
Don't know/no answer	16.9
TOTAL (1,207 households)	100.0

The proportions will be more relevant when broken down by households owning different items of energy conservation. As they stand they reveal a strong potential demand for double glazing and a rather weak demand for other more beneficial investments, where energy saving is concerned, such as draught proofing.

Sources of information used on energy conservation are, in descending order, TV, newspapers, friends and neighbours, radio, and way down were salespeople, and only then EOLAS and ENFO. More than half of those availing of EOLAS or ENFO had third-level education.

Replies to the question asking whether an item saves money in the long run are shown in Figure 4.7. In a sense, in this question, we have asked our own respondents to give us their rating of the worth of the conservation items which we can compare with the experts' ratings in Figure 4.1. Apart from the extremely high proportion believing that double glazing is a good investment (which may be true in some cases, though more in non energy-saving terms), the rest of the items' ratings are in a very similar order as given by the experts, as Figure 4.7 shows. The items are listed in the experts' descending order of worthiness.

Figure 4.7: *Buying the item saves money in the long run*

	% of respondents saying	
	YES	*DON'T KNOW**
Lagging jacket	84.0	9.5
Attic insulation	85.9	10.0
Draught-stripping	74.1	15.2
Insulating Curtains	44.7	38.4
Cavity wall/block insulation	53.2	31.2
Dry lining of walls	59.4	29.8
Low energy light bulbs	47.9	40.2
Double glazing	86.1	8.3

* "Don't know enough about it" was the wording on the questionnaire.

Finally despite the quite low levels of conservation items actually installed, people consider themselves pretty energy conscious overall. One third claim to be very energy conscious, and more say moderately so. Less than a third say they are slightly or not at all energy conscious, the latter being only 12 per cent.

6. Further Analysis Of Influences On Take-Up

It is useful to be able to assemble the various influences discussed above and tease out their relative importance. Of course some of the influencing factors, like education and income, will be inter-related so that their relative importance will not be completely disentangled, but there should be interesting insights to be obtained nevertheless. An example of the type of output given in this exercise, called LOGIT analysis, is the decrease in the probability that a household in private rented accommodation will have a lagging jacket compared to the probability that a reference household will have one, (the reference household having to be pre-specified as, say, living in a house which is owned outright). Some results are reported here.

Looking at tenure, compared to a reference household which owns its house outright, a household in a local authority purchase scheme or having a mortgage is more likely to have attic insulation. If it is in rented private accommodation it is less likely to have either attic insulation or lagging jackets, if in a rented local authority house it is less likely to have a lagging jacket. Ownership of central heating has a clear positive effect and those using mainly oil for space heat are likely to have attic insulation, these two probably being related. The negative coefficient for ownership of a lagging jacket by gas users might indicate that the low price is encouraging waste, as hinted in some of the respondents' replies. Alternatively it may reflect an inner city low income characteristic of gas users. One would also expect people using mainly electricity to have positive ownership if they have responded to the ESB's conservation promotions but the evidence is not there and the numbers are small. By contrast, we note that for the UK, Smith (1992) finds that electricity users are significantly unlikely to possess loft insulation, despite the higher price of electricity compared to say gas. However he also found that electricity users tended to have double glazing - expensive fuel and expensive energy conservation going together. Returning to our survey, respondents who claim not to be energy conscious and don't know whether or don't think that the items save money behaved in a correspondingly logical manner. Compared to households where only primary education was completed, further education has a positive effect, particularly leaving certificate and third-level education. Higher income has a correspondingly positive effect.

The predicted probabilities associated with the above analysis for ownership of a lagging jacket are shown in Figure 4.8. The reference household owns its house outright, has no central heating, uses mainly coal for space heating, is moderately energy conscious, considers that having a lagging jacket saves money in the long run and lives in the country.

In addition to the results for variables given here, we find a significant reduction in predicted probability of attic insulation, the older the house, though possibly houses built in the inter-war years are better than those built in the early post-war years.

There is scope for much more information to be extracted from this survey, homing in for example on the "don't knows", the rental sector, the low income groups and the like. Also not yet analysed is a section in the survey on fuel efficiency and motoring.

Figure 4.8: *Predicted probabilities of having a lagging jacket*

Type of household	*Probability %*
Reference household on £110 per week	40.7
" " " £210 per week (av income)	46.9
" " " £470 per week	62.8
	Additional Prob %
Reference household but renting from LA	-13.3
" " but not energy conscious	-12.9
" " but DK saves money	-10.2
" " but is urban dweller	+29.6
" " but has central heating	+25.8

7. Conclusions

At this preliminary stage are there any pointers to policy and is intervention to be recommended, remembering that the government instruments to hand are basically exhortation and information, regulation and price?

Our study has reassured us that energy conservation in the home is worthwhile. If ownership of conservation measures were to be raised to reasonable proportions, a large number of items would have to be installed. There is plenty of scope. Figure 4.9 only covers four types of item, showing a conservative number of installations. Their respective, similarly conservative, Net Present Values (NPV) per item and the overall total Net Present Value are given. This is simply to give us a rough order of magnitude.

It can be seen that we are talking about large potential savings on a one off basis of well over £300 million, or more than 1 per cent of GNP, for just four selected items. These opportunities have not been taken up. Our behaviour is contrary - an indication of market failure.

If there is market failure now, it will still be there to some extent if energy prices rise. Therefore a policy of switching tax to energy without accompanying measures would not be totally satisfactory. We have shown that there are indications of lack of information. We could find no generally available up to date investment appraisals of energy conservation in the home. While households are a good judge of their own non-monetary costs, it is not easy for them to do the complicated monetary calculations of NPV or Internal Rate of Return (IRR). Energy conservation is a once-off investment and economies of scale are forgone if each household separately undertakes the analysis, even if it were capable of so doing. It makes sense for a central body to undertake this and publish the findings. If people do not know that investing in an item is worthwhile, they do not demand it. Suppliers get discouraged, research is discouraged and we have a self reinforcing sub-optimal state. Significant proportions of our respondents "did not know enough" or thought items would not save money - 26 per cent in the case of draught stripping, for example. The same can happen in reverse if people over-estimate the benefits - 86 per cent would install double glazing as a priority for "improving energy conservation". We have seen that people who have had shorter periods of education need to be targeted, through the media they use as well as through stronger promotion of information schemes such as EOLAS's Energy Phone.

Figure 4.9: *Conservative calculations of NPV of 4 items*

Items	*(thousands)*	*NPV per item (£)*	*Total NPV (£m)*
Lagging jackets	300	322	97
Attic insulation	200	566	113
Draught proofing	400	218	87
Low energy bulbs	500	30	15
TOTAL NPV OF 4 ITEMS:			312 million

We have also shown that non-appropriability, this is inability to reap most of the benefits for oneself, is a factor. Non-appropriability applies to households in rented properties for example. They are significantly less likely to invest in energy conservation (for instance, do we turn off the office lights?). This is separate from income considerations it appears. There is a case for regulation here perhaps, though targeting the privately rented sector is not easy. It would be interesting to see how dwellings in this sector would be rated by the rating scheme, NICER (National Irish Centre for Energy Rating), for example. Belatedly, regulations have tightened up building standards. We saw how unsure respondents were on items like cavity wall insulation. If house purchasers are unable to specify that they want indisputably worthwhile features in their homes, the authorities obviously have to step in with regulations.

Our survey has also shown that income is, as expected, an important factor, though if the credit market operated smoothly this should theoretically not be a strong influence. The fact is that low income households do not have reasonable access to credit. There is another spiral at work here. We saw that households with central heating did have conservation items. As big energy users the investment presumably pays handsomely. Without insulation, poor households are losing heat, so useful heat is expensive, consequently they use little of it. Hence investment in conservation is perceived as "not worth it", which indeed it might not be. If they had access to credit and could insulate, they might use more energy. Is that a problem ? No, welfare is improved so it is still worth doing.

Price measures have been used by government in the past to help people with the financial cost. The attic insulation scheme introduced in 1980, for example, gave grants amounting to £1.27 million in 1980-82. The home improvement grant scheme of the mid-1980s spent £40 million on doors and windows. It is not clear how much was spent on double glazing. The ESB offers free credit and cut-price deals on energy saving items. Though no detailed analysis of take-up has yet been undertaken, they appear to be availed of more by the high income groups. Other price measures are being used to a small extent at present through Energy Action, which with the aid of a government grant insulates houses of the elderly for free. Energy Action have insulated over 4,500 houses, mostly in the Dublin area.

Assessment of these conservation schemes can only be tentative but they appear to have had some success. If one's aim is to achieve most energy saving at minimum cost to the state, it may be a sensible strategy to target big energy users who are easily alerted - that is the categories who have already shown a tendency to install energy saving measures. On the other hand other groups who have not yet bought their houses but are likely to become large energy consumers of the future, these too should be alerted, especially because when they become house buyers they can press their demand for conservation features. Meanwhile low income households should also be helped with grants for insulation as a welfare measure and Local Authority houses should be supplied with lagging jackets. In other words a broad policy of several measures is called for.

Behaviour of course is the final determinant of energy use. Leaving doors open, opening windows rather than removing the pullover, omitting to adjust the timeswitch or thermostat have adverse effects. Such behaviour is influenced by price.

In general we know that price does have an effect on energy demand and that pollution taxation is sensible, but what we show here are the areas where snags could be encountered and why. There have been state interventions over the past decade or so to address these snags. These interventions have in fact been in the right areas but on a minor scale and it is not clear that they were targeted correctly, either to the right items or right people. With the possible switching of taxes in the future to pollution and hence to energy, there now needs to be a reassessment of past state actions and strengthening of their effectiveness in the light of our current knowledge.

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Chapter 5

THE IMPACT OF A CARBON TAX ON THE COST OF PEAT ELECTRICITY GENERATION

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1. Introduction and Background

The European Community (EC) has come to have a considerable influence over the energy policies of its member states. To date, its main concerns have been to increase the degree of competition in the internal energy market and to lessen the environmental impact of energy use. These objectives are likely to continue to dominate the Community's energy policy in future. The traditional energy policy goals at national level have not yet received as much attention at EC level.

As the EC's influence over Irish policy increases, it is important to reflect on how the changes in policy emphasis emanating from Brussels will impact on the energy scene in Ireland. In contrast with the Community's approach, the Irish energy sector has been influenced by a policy regime which, until recently, has stressed the more traditional objectives - low cost energy, security of supply, development of indigenous energy resources and diversification of sources of supply.

[1] Thanks are due to John Fitz Gerald of the ESRI, for practical assistance, constructive comments and advice in the preparation of this paper and the dissertation on which it is based. I am also grateful to colleagues in Analysis Section, Department of Finance, the Department of Statistics, Trinity College Dublin, the Department of Energy, the Environment Unit of the ESB, and Bord na Móna for information provided and useful comments. Any errors made are, of course, my own. The dissertation was submitted for the Public Sector Analysis course at the Department of Statistics, Trinity College Dublin. Participants on the Public Sector Analysis course are sponsored by the Department of Finance. The writer is Analyst for the Committees' Secretariat of the Houses of the Oireachtas; however, neither the dissertation nor the paper necessarily represent the views of the Department of Finance, the Office of the Houses of the Oireachtas nor any of its Committees.

The use of peat as a source of primary energy and for electricity generation is a feature of the Irish energy sector that is unique in European terms.

The peat industry has had a significant role in the social and economic life of the Midlands and West of Ireland, admittedly at a cost to the nation. The implications of EC energy policy for this industry have not yet been comprehensively addressed in public.

This Chapter takes the example of a particular EC energy policy measure aimed at the environment - the proposed carbon tax - and looks at how it might affect the cost of peat electricity generation to the economy.

The aim of this Chapter is to highlight the kind of issues involved for energy policy decision-making, both in relation to the tax and the future of peat electricity generation. Definite conclusions or recommendations on particular courses are not made here. However, it is important to identify the issues that will arise for Ireland as EC energy policy is being formulated, so that potential problems can be addressed at an early stage. This especially applies to the carbon tax proposal, where negotiations are continuing.

The structure of the Chapter is as follows: first, the cost of peat electricity generation to the economy in 1990 is calculated; second, aspects of the carbon tax are set out and the impact on the cost of peat electricity generation is discussed; the final section reflects on the benefits that the peat electricity generation programme have provided and draws some conclusions.

2. The Cost of Peat Electricity Generation

At present, peat is the most expensive fuel for the Electricity Supply Board (ESB) to use for electricity generation. A comparison of the ESB's unit fuel costs in 1990 shows that the average unit of peat-fired electricity cost 3.46p, almost twice that of oil- or gas- generated electricity (1.76p or 1.75p respectively)[2], and almost three times that of coal (1.21p).

Many reasons are advanced for the difference in the ESB figures between the cost of peat electricity and the cost of electricity produced from any of the other fuels it uses. The main ones are the relatively low conversion efficiency of peat and the high cost of the peat.

Peat is transformed into electricity at a low level of efficiency relative to other fuels in the ESB's generation system. In 1990, peat was converted to electricity at 26 per cent efficiency; the efficiencies for the other fuels (coal, gas

[2] The ESB's Annual Report and Accounts for the year ended 31st December 1990 lists the unit fuel costs for all 15 thermal stations in the ESB's generation system. Unit fuel costs measure fuel expenditure per unit electricity output produced (Kwhr); for example, the unit fuel cost of a peat station is the peat electricity output of that station divided by the cost of the peat used to produce that output. The average milled peat figure is derived from the Annual Report by dividing the total number of electricity units produced from milled peat by the ESB's total expenditure on milled peat.

and oil) varied from 36 per cent to 39 per cent. The low efficiency is, in turn, partly a reflection of the age distribution of peat plant as technological advance has steadily increased the efficiency of new thermal generating stations. In addition, as plant ages thermal efficiencies decline. At present, almost three-quarters of peat capacity is over 20 years old, much older than the generating plant which burns coal, oil and gas, so that peat's relatively lower efficiencies are not surprising.

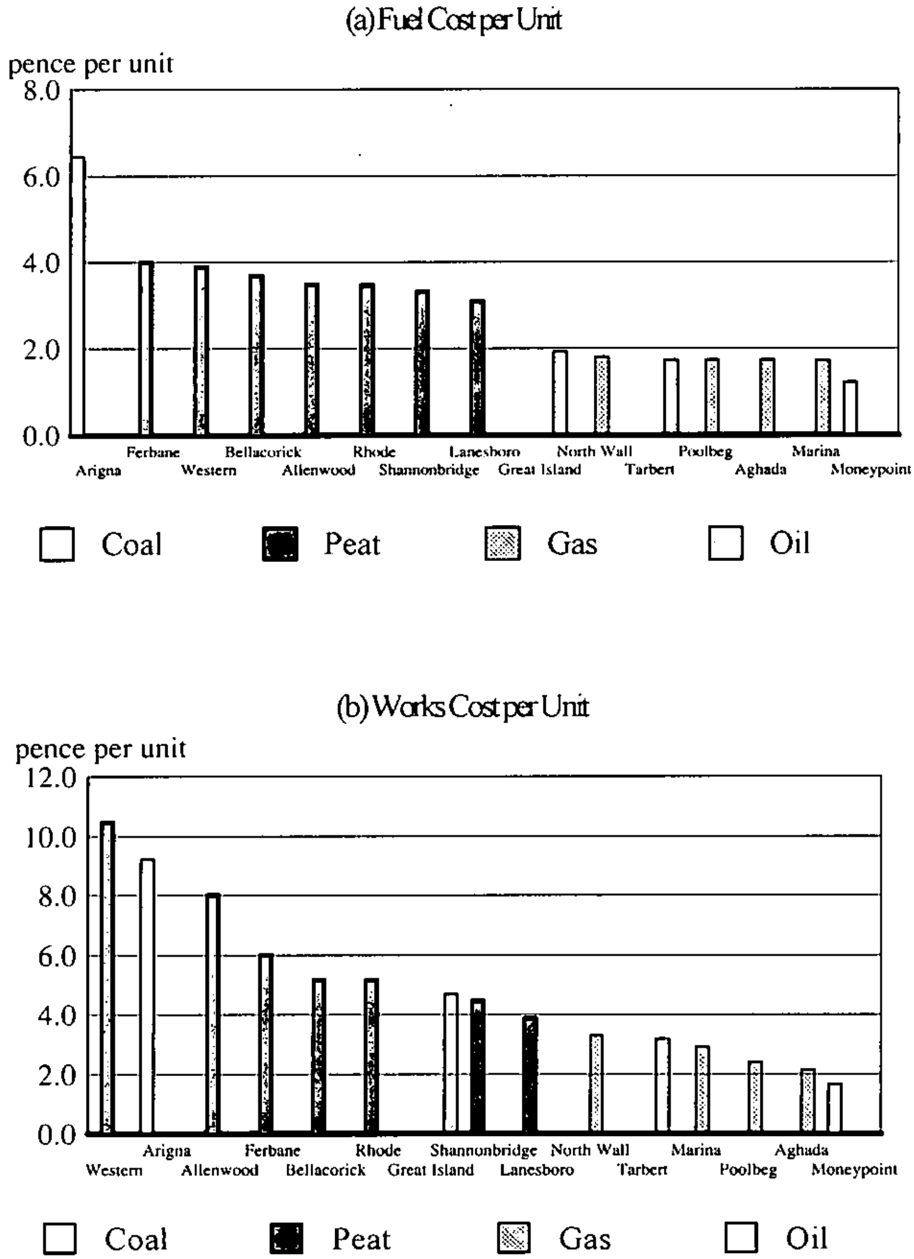
The cost of the basic fuel input - peat - is also reflected in the ESB's unit fuel costs differential. If Bord na Móna, the state owned peat industry, is to break even, all its costs must ultimately be covered by the revenue it receives from its customers, the ESB among them. The cost of the peat to the ESB is then, in turn, a reflection of Bord na Móna's major costs, which comprise labour - due to the labour intensity of milled peat harvesting - and debt interest. While Bord na Móna's costs are passed on to the ESB and ultimately reflected in the cost of peat-generated electricity, detailed analysis is required to determine whether the underlying costs reflected in the electricity unit costs are truly costs as far as the economy as a whole is concerned.

There is also a differential between peat and the alternatives as regards the other costs of electricity generation, apart from fuel. Since the process of peat electricity generation is more labour intensive than that from other fuels, there is a labour unit cost differential: ESB figures (ESB, 1991) show that manning levels in peat stations were over three times those of the oil stations and over four times those of the coal and gas stations in 1990. These staffing levels reflect to a certain degree the comparative age of peat plant, as manning levels at all stations have decreased over time. The age factor also results in higher maintenance costs at some of the older peat stations than at newer stations based on alternative fuels.

Individual Stations

The unit fuel cost differential is an average of the five milled peat stations in the ESB's system. Figure 5.1 compares the unit fuel and works costs of all 15 stations in the ESB's thermal generating system. It shows that there is a considerable variation in the size of the fuel cost differential between the different stations in the system. For example, Tarbert oil-generating station is 1.38p cheaper in fuel cost terms than Lanesboro (a relatively new milled peat station), but almost a penny cheaper again (2.29p) than Ferbane, most of which is almost 30 years old. The difference in the size of the fuel cost differential reflects the improvements in efficiency that have occurred and the age of the stations. Lanesboro is a relatively new station (half commissioned in 1983 and the other half in 1966) and operates at an efficiency higher than the milled peat average of 26 per cent. Ferbane has a lower than average efficiency.

Figure 5.1: *Baseline Cost per Unit of Electricity Sent Out*



Unit works costs measure total non-capital costs per unit of electricity produced. Non-capital costs comprise fuel, labour, maintenance and rates. The ESB state that it is inadvisable to compare unit works costs as direct indicators of station performance. This is because the other components of works costs, apart from fuel, are essentially fixed. Therefore unit works costs reflect the level and type of usage of the plant. The more a station produces relative to its potential output, the lower the unit works costs. For this reason, a comparison between similar stations, one used to produce only half of its total potential output, another which is used for maximum production, is not valid. Each station must divide similar levels of fixed costs over different outputs. The type of usage of the plant is also a factor. If similar outputs are produced in one station consistently throughout the year and in another in short bursts followed by long periods of inactivity, costs will be higher in the latter. This is because stopping and starting production are the costly parts of the generation process.

Cost to the Nation

The next task is to move from the cost differential between a single unit of peat fired electricity and that of other fuels to a general cost to the nation of peat generation. The cost has been calculated in a number of exercises so far, for example, Scott and Convery (1989), DKM (1991), and Lang (1983). The approach has been to assume that there is a cost penalty on the Irish economy equal to the peat output multiplied by the difference between the cost of producing that peat output in a peat station and the cost of producing it somewhere else. It has therefore been calculated by multiplying some version of the cost differential by the peat output involved.

The assumptions underlying the transfer to a cheaper location must be examined so that the correct differential can be selected. It was assumed that an immediate and hypothetical cessation of peat generation happened in 1990 and the cost of peat electricity generation was estimated by calculating the cost saving which would accrue. If the peat stations were closed, their output of 2000 million units of electricity would have to be produced elsewhere. Whether a net cost or saving would result depends on the difference between the cost of peat generated electricity and that of alternatives.

Since this potential saving is forgone because peat generation is, in reality, maintained, it is taken to be equivalent to the cost of the continuation of peat electricity generation. It was necessary to allocate the electricity generated from peat to an alternative generation option under this scenario. It was decided for simplicity to distribute the peat output to existing stations, by assuming that the peat output could be accommodated within the current generation system, without any potential capacity constraints. In this way, the capital cost implications of the need for investment in additional capacity could be ignored. Since the assumption regarding absence of capacity constraints would not be tenable over a number of years, the exercise was carried out for only one year.

The Tarbert oil station was selected as the alternative source of the peat fired electricity for the following reasons:

- All stations underproduce electricity for system reasons, but the oil stations in 1990 produced far less output in relation to their potential than the gas stations did. Therefore the gas stations had comparatively less available capacity for producing additional electricity than the oil stations.

- Even if they had available capacity, some of the gas stations are too small - Marina and North Wall for example - to take on the total peat output.

- There are constraints on any additional electricity coming from gas arising from the fixed quantity allocated to electricity generation; the supply of gas to the ESB is exogenously determined and it could not easily purchase more gas in the short term.

- Future gas supply is limited in the medium term, unless new supplies are discovered, until the interconnector commences operations.

- A costing based on Tarbert would be reasonably representative. In 1990, Tarbert was cheaper in fuel cost per unit terms than Aghada, Poolbeg and North Wall stations (all mixed gas/oil stations) and Great Island (an old oil station) and more expensive than Marina (a gas/oil station) and Moneypoint (a modern coal station).

- There is no scope for coal-generated electricity to take up the slack because Moneypoint is already producing the maximum level.

- There are only two oil stations - Great Island cannot contribute a significant proportion of the output needed because of its relatively small size.

- Tarbert on the other hand only produced 20 per cent of its total potential capacity. If it produced to the level of 70 per cent - comparable to the load factor at Moneypoint - it could have accommodated the peat electricity output.

- Transfer from peat to oil illustrates a tension inherent in energy policy because it involves a trade-off between a high cost indigenous resource - peat - and a lower cost imported source - oil. In this way, the trade-off between security, dependence and social benefits on the one hand and least cost on the other is illustrated.

While the transfer of peat output to an existing station could be feasible now, it is unlikely to be so in the future. As electricity demand rises with the growth in national output and as the peat stations approach retirement, decisions will have to be taken on providing additional peat generation capacity and/or replacing peat capacity with generation capacity based on an alternative fuel. The cost calculation is likely to be totally different in this case, because it depends on future trends in the prices of alternatives fuels, technological developments in peat electricity generation and its alternatives and the costs of various environmental standards as they will apply to generation stations in the future. However, the principles used here could be adapted to that exercise.

There is no treatment in this Chapter of the implications for the Exchequer in the costing of a transfer to Tarbert. For example, the gain to the Exchequer of the additional excise duty on the increased quantities of imported oil and the loss of peat workers' social insurance contributions are ignored. Neither is the impact of the additional taxation on the finances of the commercial state energy companies discussed. It is important to note that what might be an additional cost, from the perspective of the commercial state energy companies, might be balanced out by a gain elsewhere, in the energy sector or in the economy as a whole. For example, an increased yield from energy taxation collected from the state companies, and seen by them as increased costs, provides additional resources for reducing taxation elsewhere or increasing Exchequer expenditure.

No attempt is made in this Chapter to include an estimate of the environmental costs caused by peat electricity generation. To the extent that the transfer to another fuel type would reduce environmental damage, the amount of the cost saving would increase beyond that shown in the calculations below.

The Calculation of the Gross Fuel Cost Saving

Having chosen the station to which the peat output is to be transferred, the calculation of the saving in fuel costs is, in simplified form, the differential between the unit fuel cost at Tarbert and the average peat unit fuel cost multiplied by the total peat output, as shown in Table 5.1.

Table 5.1: *Calculation of Gross Fuel Cost Saving*

Peat Electricity Output		*Average Unit Fuel Cost Of Peat*		*Unit Fuel Cost Of Tarbert Output*		*Total Fuel Cost Saving*
2,000 m units	*	(3.46p	-	1.736p)	=	£34.5m

In order to take the analysis further, there are three questions to be asked:

- does the fuel cost saving represent a genuine saving to the economy?
- are there any further savings to be added to the saving in fuel costs?
- are there any additional generation costs arising at Tarbert to be offset against the saving?

In order to answer the first question, it is necessary to exclude sunk costs and depreciation - only cash items represented real savings.

Sunk Costs

The treatment of sunk costs is a distinctive feature of the analysis presented in this paper and an attempt was made to identify and exclude them from the computation. In general sunk costs are excluded from computations of this type because the money has already been spent and the various alternatives under review make no difference to the fixed costs. Bord na Móna's debt service costs for its State-guaranteed borrowings are sunk costs. Much has been written about how these borrowings arose and the difficulties posed for Bord na Móna by its current debt burden (Tithe an Oireachtais, 1991)[3]. The important point is that the interest costs arise in relation to capital already spent and the debt service costs would still have to be met by the Exchequer and the economy, even if the peat electricity generation programme was discontinued. This is because the borrowings on which they are payable are State-guaranteed. The significant question is to determine whether, and, if so, to what extent, the continuation of peat electricity generation makes a contribution to these fixed costs.

It has been stated above that the peat unit fuel costs reflect the price of peat charged by Bord na Móna to the ESB as well as peat's low efficiency. This is because the revenue Bord na Móna receives from the ESB for the quantity of peat supplied must enable it to cover all its costs. Since the price of peat enables Bord na Móna to meet both its debt service and depreciation costs, the unit fuel costs based on that price include sunk costs and non-cash flow items. On exclusion of these items (Bord na Móna interest and depreciation combined amount to £28.9m in 1990) from the gross fuel cost saving of £34.5m, the net fuel cost saving comes to £5.6m.

It is also necessary to pose the second and third questions. Would there be any additional savings as a result of the switch to oil and would there be any additional costs arising at Tarbert to be offset against these savings? Staff and maintenance costs would no longer be incurred at the peat stations, giving rise to further savings over and above the fuel costs. In addition, the ESB state that the increase in Tarbert's output could have been absorbed at little or no additional staff or maintenance cost there. Therefore, the transfer would result in peat stations' total costs under these headings (£24m in 1990) being saved without any additional costs arising at Tarbert, bringing the estimate of the total saving on cessation of peat electricity generation to £30m approximately (£24m plus £5.6m).

The net saving forgone of £30m may be viewed as the annual short-term cost of peat electricity generation. This cost burden is passed on to electricity consumers in the form of higher electricity prices. Consumers may be seen as providing an indirect subsidy to peat electricity generation through the higher

[3] The discussion of Bord na Móna's debt burden in this report is especially useful.

prices. The above calculations have been based on the differential between the average milled peat unit fuel cost and Tarbert unit fuel cost, but the outcome does not differ if the individual peat station's costs are used instead. The details of the calculations based on the stations' costs are contained in the Appendix.

The Future for Peat Electricity Generation

Peat electricity generation will continue into the future, despite the cost burden it imposes on the economy. This clashes with one of the goals of energy policy, the requirement for low cost sources of energy. The continued use of peat as an energy source is supported by Government because the extra cost is seen as counterbalanced by certain benefits to the economy in terms of security of supply and social benefits in Midland areas. For the short to medium term, it seems likely that peat electricity generation will continue and that the ESB would appear to be a guaranteed market for peat - the companies finalised a contract in 1990 governing peat deliveries for the five year period from 1991 to 1996. It is not known whether the ESB will continue to purchase peat for generation after 1996. As long as peat electricity generation continues, using the same amount of peat and the current plant, the economy will bear a cost burden in the region of that calculated above, but will also obtain the associated benefits. However, the long-term outlook for peat electricity generation is uncertain. This is due to the age of peat plant and new directions in energy policy, at Irish and EC level.

The increasing influence of the EC on Ireland's energy policy threatens the long-term future of peat electricity generation because of the differences in emphasis between EC and national policies. The greater priority attached by the EC to environmental protection and free trade in energy markets has already been noted. The completion of the internal energy market and the encouragement of free trade in energy products where possible will run counter to the practice of continuing State subsidies to public energy companies operating throughout the Community. In a competitive market, peat generated electricity will have to cost a similar amount per unit as that generated from other fuels, because otherwise private generators will not use it and/or private distributors will not purchase it, when they can turn to cheaper alternatives. The increased environmental dimension will threaten the indigenous energy-using or producing industries based on heavily polluting fuels, by the issue of new directives containing standards and regulations that heavily-polluting energy industries will find costly to comply with.

Even if these energy policy factors do not operate to the total disadvantage of peat electricity generation, its continuation at the current level into the future depends on the construction of new peat generation plant. Much of the present peat generation capacity is due to be retired in the short to medium term. A decision will have to be made soon to replace plant due for retirement with either new peat or alternative plant; in the latter eventuality, the amount of peat electricity generation would be reduced. Any proposal for the replacement of retired peat capacity with a new peat station will presumably be the subject of an economic and energy policy assessment. There are many factors affecting the comparison of the capital and running costs of peat generation capacity with alternative fuel options. Consideration of these factors is beyond the scope of this paper, but the issues involved would include the following: the future outlook for alternative fuel prices; the technical and economic feasibility of improving efficiency in peat electricity generation; future directions of EC energy policy; the method of financing the replacement capacity.

In conclusion, peat electricity generation imposes a short-term annual cost on the economy, estimated at £30m via increased prices faced by electricity consumers. Future trends in EC environmental control and free trade directives as they relate to electricity generation may restrict Ireland's discretion to protect the position of the peat industry in this way. Any analysis of the economics of new peat capacity must be conducted having regard to the full energy policy context, at both Irish and EC level.

3. The Impact of a Carbon Tax

As has been stated, the EC's energy policy places particular emphasis on the environment and competition. This policy is not yet comprehensive. The full range of policy objectives found at national level, including the traditional objectives of energy policy, security of supply, diversification of fuel types and protection of indigenous energy industries is not covered. The EC's attempts to develop policy in the competition and environmental areas have, to date, addressed only two components of a multi-faceted problem at national level, Helm (1991).

The EC has adopted a target of stabilising the carbon dioxide (CO_2) emissions resulting from energy use and has proposed a tax on energy use to achieve this target because of its concern with the environment. The release of CO_2 into the atmosphere - resulting from energy use, certain industrial processes, deforestation, etc. - is thought to have a role in increasing global temperatures gradually over time, a phenomenon known as global warming. The effects of global warming are unpredictable but may lead to serious consequences for future generations in changing global climate, settlement patterns and agricultural practices. There is widespread agreement that it is worthwhile to attempt to prevent any further deterioration. For this reason, the EC has addressed the contribution of energy use to this problem by proposing a number of measures, including a carbon tax on energy use.

In economic terms, the objective of the carbon tax is to make the cost of energy reflect the environmental externality caused by its CO_2 emissions. By imposing the tax, policy makers would hope to internalise the contribution of energy use to the cost of global warming. This is done by adding to the private market cost of energy currently borne by energy consumers an amount intended to represent the cost of its contribution to global warming.

It is proposed that the carbon tax would apply to the input that causes the environmental impact, rather than on the actual pollution or emissions as is normal with pollution taxes. It is easier to tax the input giving rise to the invisible pollution in this case. There is, as yet, neither a technologically nor economically feasible method of extracting and disposing of the CO_2 resulting from fuel combustion. Therefore the alternative option of designing a subsidy to encourage expenditure on such abatement of CO_2 emissions does not arise at present.

Effect of Carbon Tax

The Commission hopes that producers and consumers would reduce their use of carbon-rich fuels - peat, lignite, coal and oil - after the imposition of the tax. This is expected to happen because of the increase in the cost of consuming those fuels: carbon content would be part (or all) of the basis for levying the tax. The tax would therefore provide an incentive for energy users to economise on the quantity of carbon-rich fuels consumed and/or to substitute for them fuels of a lower carbon content, such as gas or renewable energy. By reacting to the tax in these ways, producers and consumers could reduce their carbon tax bills and simultaneously generate less carbon dioxide emissions.

Alternatively, some energy consumers may continue to use the same amount and type of fuels as they did prior to the imposition of the tax and opt to bear the tax burden instead. The fact that an externality tax is not assured of success in changing behaviour is one of its drawbacks. In contrast, other measures such as quota restrictions, provision of information, regulation, etc. may be more successful in this regard, but they also have their associated disadvantages. Quotas sometimes achieve the target level of output at a greater cost to the economy than is necessary.[4] The carbon tax is only one part of the EC's "no regrets" strategy.

Many Versions of the Tax

Many aspects of the tax proposal have to be finalised; those details which would impact on the cost of electricity generation include the tax basis and the method of calculating the tax on electricity generation. It has not been decided whether the tax should be calculated on the carbon or energy content of a fuel or

[4] Regulations are more appropriate where a fixed target must be met over a short time period, whatever the cost. They usually involve a fixed quota being applied to each firm or household regardless of circumstances. The problem with this is that firms cannot adjust their pollution control expenditure to the point where its marginal benefit equals its marginal cost because they are forced to spend on pollution abatement to conform with the quota restriction. Some firms may only reach this quota at vast expense while others may be able to arrive at it very cheaply. This increases the overall cost to society of reaching the efficient output. Furthermore, with a quota restriction, firms need only reach the quota applied to them; they need not engage in further abatement expenditures that could possibly benefit the economy.

Taxes on the other hand are less costly and provide a more correct incentive at individual level. They are less costly for the economy as a whole because only those firms which can reduce pollution cheaply do so. Firms which can only do so at vast cost pay the tax instead. Taxes apply at all levels of output and therefore are a continuing incentive to correct behaviour.

a combination of both. The EC's present carbon tax proposal is for a combined energy/carbon tax, for a number of reasons. First, the Commission wishes to encourage efficiency in the use of the existing fuel mix, as well as switching within that mix to low-carbon fuels and the inclusion of an energy component in the combined tax does this. If the tax is on energy input, there is an incentive for users to consume less energy, whatever fuel is used. Second, the inclusion of an energy component ensures that nuclear power is not given an unintended advantage in the post-tax fuel cost relativities (nuclear power emits no CO_2).

The tax as applied to electricity generation may take various forms: it could be levied at the fuel input or at the electricity output stage of the generation process. Given the mix of fuel involved in electricity generation, it seems easier to calculate the tax on the carbon content of a fuel as it is input to the process, rather than on the energy output, since the CO_2 emissions resulting from the production of any output is dependent on the carbon content of fuel input to the combustion process. The energy component could be applied at the raw fuel input or the electricity output stage, both of which can be expressed in a common energy measure. The input tax - carbon or energy - ensures that more correct incentives face the electricity generators. In this way, they are forced to switch to low carbon fuels and be more efficient in the use of fuels, regardless of carbon content. In the case of taxing the input - whether energy or carbon input - it would be difficult to link each individual consumer with the fuel type used to produce the electricity and therefore to calculate the carbon tax properly. In fact, the consumer would be required to pay a carbon tax which referred to the total carbon tax payable by the ESB averaged over the fuel mix and calculated over a previous period.

The output tax facilitates transparency in so far as electricity consumers are concerned because it is easier to calculate: it is levied on electricity output regardless of the type of fuel used to produce it. Transparency in turn makes it easier to introduce tax rebates for high energy users and for firms exporting outside the tax regime. A further characteristic of the output tax is that it does not discriminate between efficient and inefficient fuels, so that the electricity generator is not encouraged to switch fuels. Therefore, it is more likely to preserve the existing fuel mix.

The final design of the tax in relation to these and other matters will determine the effect on relative prices between energy and other goods and between the different types of energy, and hence on the types of incentives provided. The outcome in terms of incentives will, in turn, influence the amount and type of adjustment by energy consumers, including electricity generators.

In accordance with the theoretical preference that externality taxes should be used to replace other distortionary taxes, the Commission has suggested that the tax should have a neutral effect on the overall national tax burden. This means that carbon tax revenues could be used by member states to replace other taxes currently paid into the Exchequer, such as those on labour (Fitz Gerald and

McCoy, 1992). The tax neutrality condition is still the subject of negotiation between member states.

Effect of Tax on Fuel Cost Differential

As discussed above there are potentially many versions of the carbon tax. Electricity generation could be taxed on the energy or carbon fuel inputs used to produce electricity or some combination of both. Alternatively, all the tax could be imposed on electricity output. Another version of tax would be to combine the output element with a carbon input tax.

When all of the above possible versions of the carbon tax are applied, the unit fuel cost differential between peat and oil widens in all cases except one, because of the higher carbon content of peat and the relative efficiencies of both when used in electricity generation. The widening of the differential ranges from 1.7p to 2.83p, depending on the type of carbon tax used in the calculation. The largest increase in the differential occurs in the case of a tax levied totally on the carbon content of the fuel input because peat emits 40 per cent more carbon dioxide than oil per equivalent unit of energy input. However, the differential also widens with any combination involving a carbon component or an energy input component, because of the lower conversion efficiency of peat relative to oil. The unit fuel cost differential remains the same only if the tax is wholly based on energy output.

The size of the fuel cost differential affects the outcome of the excess cost computation, and therefore the widening of the differential would point towards a greater excess cost, assuming the quantity of peat consumed in electricity generation remains constant.

Given that peat consumption by the ESB will be static up to 1996, the result of the imposition of the carbon tax is that the tax-inclusive (or gross) cost of peat electricity generation would increase by the amount of taxation involved. It is not known whether, on imposition of the carbon tax, the arrangements between Bord na Móna and the ESB covering peat deliveries up to 1996 could or would be altered. For the present, it seems reasonable to assume that the quantity of milled peat used in electricity generation will not decrease before 1996. If so, the ESB will not be able to react to the carbon tax as it would in the absence of an agreement and switch from peat to lower carbon fuels.

At this point, it is necessary to clarify from what perspective the analysis is being carried out. From the ESB's viewpoint, it would have to bear an additional cost because of the greater tax-inclusive price of the peat which it is contracted to purchase from Bord na Móna in any case (except where the tax is levied 100 per cent on energy output). However, the tax portion of its total expenditure on peat must be handed over to the Exchequer in much the same way as any other tax. Depending on the format of the tax, the increased cost to the ESB for all fuels would range from £43m to £151m[5]; given that it spent £227m on fuel in 1990. The percentage increase in electricity prices on the 1990 base required to cover this additional cost would vary from 6 per cent to 20 per cent.

Increase in Excess Cost to Nation?

The position is different from the standpoint of taxpayers and electricity consumers in general: the after-tax excess cost remains the same as the original excess cost. This is because the cost of the tax to electricity consumers - who are beneficiaries of Government expenditure in the areas of health, education, etc. - is cancelled out by a contribution of tax revenue from the peat electricity generation sector. This contribution is available to increase expenditure or to reduce taxation, whether within the energy sector or outside it.

It has been stated that the Commission intends that the introduction of a carbon tax should not increase the overall burden of taxation at a national level, so that the revenue from the tax would probably be used to reduce taxation elsewhere. If, for example, the reduction in taxation elsewhere in the economy increased allocative efficiency, the tax revenue portion of the new total excess cost could be offset at least partially or even totally by the increased efficiency of the tax system. From society's point of view, the carbon tax does not affect the net after tax cost of continuation with peat generation.

From the point of view of the commercial State energy companies and the energy sector, the tax raised may be an extra cost if it is lost to the sector. If the revenue was returned to the energy sector in the form of a subsidy or used to relieve social insurance contributions the incentive to hire labour in these companies would be increased, post carbon tax, and the same excess cost could generate more jobs. However, a return of revenue in the form of a subsidy for social benefits say, would effectively defeat the fundamental purpose of the tax: to adjust the cost of energy consumption to reflect its impact on global warming.

Carbon Tax, Excess Cost and Conflicts in Energy Policy

The carbon tax has been proposed as an environmental measure by the EC. Excluding peat from the effects of the measure may accord with the national objective of protecting Ireland's indigenous peat industry. However, it makes it more difficult for the tax to achieve Ireland's emission target under the Community's CO_2 strategy. Even if the revenue were not returned to the energy sector, the same problem would arise if, after imposition of the tax, peat consumption continues at the same level. The ESB, in its discussion of strategies for meeting the CO_2 targets, state that substituting gas for peat in electricity generation is the most effective fuel switching programme available, but also that the use of this strategy is constrained for security and social considerations (ESB,

[5] This assumes that the tax is levied at the full rate proposed for the end of the decade, that is, the equivalent of $10 per barrel of oil.

1992). This trade-off between environmental damage and regional and security benefits adds a further complication to the peat debate, for policy-makers.

Impact on ESB Fuel Cost Differential - Short vs. Long Term

As far the ESB is concerned, peat-generated electricity would cost even more compared to that produced from other fuels, if the tax was imposed. The size of all the unit cost differentials would change - not just between peat and the other fuels but also between the alternatives, gas, oil and coal. This would radically affect existing incentives for fuel switching between all fuels used in electricity generation and as the ESB reacts to the new incentives, the quantities of the various fuels used in electricity generation would change. However, despite the incentive to switch away from peat, Bord na Móna's peat energy business in the short to medium term, up to 1996, will not be affected because the quantity of peat to be delivered to the stations is already determined.

However, the picture changes when the long term is considered; over this time scale the ESB would have more freedom to switch between the fuels from which electricity is generated in reaction to the newer post tax relative price differentials. The increase in demand for electricity coupled with the need to retire some peat capacity over the next five to ten years implies that additional capacity will have to be commissioned in the medium term.

The carbon tax adds an extra dimension to the cost analysis of future peat generation options because the size of the resulting increase in the running costs of any new station depends on the fuel type it will use. The justification for replacing the peat electricity generation stations in the post-tax era would be weakened from the ESB's point of view because peat electricity generation would cost even more relative to other fuels than it does now. However, it is important to conduct the economic analysis of new capacity in the context of the entire economy and the cost burden, if any, imposed on the economy by the additional investment in peat generation plant, rather than limiting the exercise to the ESB's costs alone.

If the thermal efficiencies of peat generation could be improved in a new station to such a degree as to maintain or even narrow the pre-tax fuel cost differential, the outcome might be different. Since present peat efficiencies are 26 per cent on average, it would be interesting to know how feasible significant increases in efficiency are and also to determine the effect of the carbon tax on a peat station capable of achieving a thermal efficiency over 30 per cent. Similarly, if other fuels increased significantly in price - as oil did in the 1970s - the relative fuel differential would also change.

In conclusion, the short term annual cost burden imposed by peat electricity generation on the economy, estimated at £30m, does not change when the carbon tax is considered. However, the tax does significantly affect the fuel cost relativities as far as the ESB is concerned. It is in the medium to long term, when peat contracts fall due for renewal and peat generation plant due for retirement must be replaced, that the adverse impact of the carbon tax on the unit cost differentials between peat and its alternatives may influence decision-making, by the ESB and any other generators or distributors which have entered the Irish market by then.

4. Conclusion

It has been shown that peat electricity generation imposes a short-term annual cost burden on the economy, estimated at around £30m in this Chapter. This excess cost is paid by electricity consumers, who face increased prices. This situation does not change when the carbon tax is considered because the tax revenue portion of the new total excess cost is available to provide offsetting benefits to the nation.

Because of the existence of sunk costs buried in the fuel cost differential, the calculation of the cost to the nation is a more complicated question than just the calculation of the difference in cost between peat and its nearest rival. This paper shows that the excess cost burden is around £30m rather than nearly £60m, because of sunk and non-cash-flow costs of Bord na Móna. The calculation is likely to be more complicated once a longer time scale is considered; in this situation, the construction of new capacity and associated costs has to be included in the computation.

Over the long term, the future of peat electricity generation is uncertain. Future trends in EC free trade directives as they relate to electricity generation may restrict Ireland's discretion to protect the position of the peat industry and maintain it into the future. The EC's emphasis on the environment will also affect peat because of the likelihood of measures being drawn up to reduce other pollutants produced by the generation process, apart from carbon dioxide emissions. Because of the age of the existing plant, decisions will have to be made over the next five years whether to replace plant due for retirement. The ESB calculations are not likely to favour peat, unless the price of the peat is reduced, the price of the alternatives rises and/or significant improvements in the efficiency of peat generation are realisable. Any analysis of the economics of new peat capacity must be conducted having regard to the full energy policy context, at both Irish and EC level, and refer to the economic and Exchequer costs of any decision, as well the impact on the ESB.

The conclusion that the carbon tax makes no difference to the purely economic cost of peat electricity generation means that the problem remains: whether the original excess cost of peat electricity generation, discussed in the first section, delivers benefits that society judges to be worthwhile. The use of peat for electricity generation increases the cost of energy but this may be necessary to achieve the other goals of energy policy. Such trade-offs are implicit in the nature of energy policy, which has multiple and conflicting goals. In the case of peat electricity generation, the cost burden may be seen as counterbalanced by:

- the enhanced security of supply

 and

- the regional policy benefits.

The use of peat provides security of supply in an number of ways. First, there is a greater degree of control over a domestic energy source, such as peat, than over an imported fuel, such as oil. Second, peat provides an element of diversification in the fuel used for generation: it generated 16 per cent of electricity in 1990 in third place, behind coal (42 per cent) and gas (27 per cent). It also augments the security of the generation system because there are a number of small peat stations rather than a single large one.

The peat electricity generation programme provides regional policy benefits in Midland areas. The benefits comprise the direct employment in both Bord na Móna and the ESB (2,167 full-time equivalents in 1990), the purchases of goods and services by both companies, and the secondary jobs generated by the expenditure of incomes from direct employment and purchases. The Midlands have fewer manufacturing jobs, a lower level of manufacturing job creation and a higher level of emigration than other regions in the country.[6] If peat electricity generation was abandoned, it is unlikely that these jobs could be replaced in the short term, given the poor employment conditions in Midland counties.

The existence of policy benefits is not enough to justify the continuation of peat electricity generation in economic terms. The question must be asked at some stage whether the same benefits (security of supply and regional employment) could be achieved at lower cost by abolishing peat electricity generation and funding an alternative scheme which generated the same number of jobs. Similarly, the possibility that greater benefits - whether in the Midlands or elsewhere - could be obtained for the same level of expenditure in an alternative application (in this case in the electricity consumers' pockets) must also be considered. The necessity to justify peat electricity in value-for-money terms applies just as much to new investment as to continuation without constructing additional capacity.

In summary, the peat generation programme demonstrates the tension between the various objectives of energy policy. It illustrates the conflict between the objective of minimising cost, on the one hand, and the regional and security objectives, on the other. Peat electricity is not the lowest possible cost generation option; in fact, it imposes an excess cost burden of £30m on the economy as well as an unquantified adverse impact on the environmental. However, the programme delivers an element of security of supply and also regional benefits.

[6] The sources for the information on Midlands population and employment were the Industrial Development Authority (1990) and the Central Statistics Office (1992).

The short-term excess cost burden of continuing peat electricity generation can be quantified. It is the fundamental problem and remains so under the carbon tax. The size of the excess cost burden would be different over the long term when new capacity is considered, but in both cases, the effect of sunk costs must be taken into account. The acceptability of the cost of peat generation (however estimated) to society as a whole must be ascertained. The case for peat electricity generation depends on the relative priority attaching to the security, environmental, least cost and regional objectives of energy policy.

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Appendix 5A: The Calculation of the Cost of Peat Electricity Generation: Individual Stations

The calculation of the cost of peat electricity generation in the main text is based on the average milled peat and Tarbert fuel costs. However, the outcome does not differ if the calculation is based instead on the individual milled peat stations' unit fuel cost. The calculations are shown in Tables 5A and 5B below are done in a slightly different way to that described in the main text. Here, the depreciation and the debt interest costs were deducted from Bord na Móna's revenue from the ESB and that amended revenue divided by the quantity of peat delivered to the stations in 1990 to arrive at a revised (or interest and depreciation exclusive) peat price. This assumes that the same price is paid at each station for a tonne of milled peat, regardless of quality. Since price depends on quality and other factors, this is not a correct assumption. Information on exact peat tonnages delivered to and prices paid at each station is not available from the companies, due to its commercial sensitivity. Peat tonnages consumed at each station were derived by working back from electricity output to energy input, using the peat thermal efficiency of 26 per cent. The tonnages were multiplied by the revised milled peat price to arrive at revised fuel costs. Finally, these fuel costs were divided by the 1990 electricity output to arrive at revised peat unit costs (Table 5A). The differential between peat unit fuel costs at each station and at Tarbert was multiplied by the particular peat station's output to give a fuel cost saving, and the operational and maintenance cost savings added on at the end as before (Table 5B).

Table 5A: *Revised Fuel Cost per unit for Peat , 1990*

Station	*Output (Million units)*	*Peat Tonnage ('000 tonnes)*	*Revised Peat Price (£/tonne)*	*Revised Fuel Cost (£ Million)*	*Revised Unit Cost (pence per unit)*
Ferbane	301	536	12.79	6.9	2.28
Rhode	299	462	12.79	5.9	1.98
Bellacorick	222	364	12.79	4.7	2.1
Shannonbridge	566	836	12.79	10.7	1.89
Lanesboro	536	740	12.79	9.5	1.77

Note: Bord na Móna interest and depreciation have been deducted to arrive at these figures.

Table 5B: *Cost of Closure of the Peat Generation Stations and Replacement of the 1990 Peat electricity Output by Output from Tarbert*

Station	*Output* (million Units)	*Revised Unit Fuel Cost at Peat Station* (pence per unit)	*Unit Cost Differential between Tarbert and Peat Station* (pence per unit)	*Fuel Saving from Switch: Differential Output* (£ million)
Western	22	3.91	2.17	0.48
Allenwood	54	3.52	0.96	0.96
Ferbane	301	2.28	0.54	1.64
Rhode	299	1.98	0.24	0.73
Bellacorick	222	2.1	0.36	0.81
Shannonbridge	566	1.89	0.15	0.87
Lanesboro	536	1.77	0.34	0.18

Summary of total cost savings:	Fuel Cost Saving	£ 5.67m
	Operational Cost Saving	£11.72m
	Maintenance Cost Saving	£12.57m
Total Savings on Generation Costs:		£29.96m

Chapter 6

ENERGY ELASTICITY ESTIMATES AND THE STABILITY OF THE RELATIONSHIP WITH GDP

Denis Conniffe

1. Why Elasticity Estimates Matter

Many issues and problems relevant to Irish energy policy are considered in the preceding Chapters. In their analyses the authors have made use of estimates of GDP and price elasticities. The GDP elasticity of a particular fuel is the percentage increase in its consumption given a 1 per cent increase in GDP. The own-price elasticity is the percentage decrease in consumption given a one per cent rise in its price and is conventionally attributed a minus sign. Cross-price elasticities with other fuels are the percentage increases in the fuel's consumption given 1 per cent increases in the prices of rival fuels. Obviously, GDP and own-price elasticities can be defined for aggregate energy in a similar way.

It is easy to see that the elasticities are necessary components of the types of analyses appearing in the other papers. In considering the impact of projected economic growth on energy demand, the GDP elasticity is central to the calculation. When discussing energy taxes, the magnitudes of own-price elasticities determine the potential impact of possible policies. Elasticities are even informative when considering competition and market structure; a fuel monopolist may have little scope to exploit his market position if cross-price elasticities are large. However, the importance of elasticities does not, in itself, justify including a Chapter about their estimation. If the elasticity estimates could be taken to be well established and stable, discussion concerning their derivation would be redundant here.

But the estimates are actually far from soundly established and there are even disagreements in the literature on how elasticities ought to be estimated. Furthermore, the reasons for this unsatisfactory situation go back to basic uncertainties about how economic growth, energy requirements and technological advance interact with each other, and perhaps also to fundamental limitations in the definitions and measurement of relevant quantities. So discussion of what elasticity values can plausibly be assigned is not only warranted, but may help shed light on some of the interrelationships of energy with other factors.

Much of the discussion in future sections will centre on the GDP elasticity, because, as will be seen, the stability of the energy to GDP relationship is a crucial issue. However, elasticities are estimated from historical data, where energy demand, GDP and fuel prices were all changing simultaneously. So the way in which the GDP relationship is specified also affects the estimates of price elasticities. The content of this Chapter draws heavily on the findings of several unpublished reports, prepared for the ESRI's Energy Policy Research Centre, following the identification of this problem of very uncertain elasticity estimates as a priority theme for research.

2. *Published Estimates of Elasticities and the Question of Stability*

The international energy economics literature has paid a great deal of attention to the relationship between energy demand, energy price and GDP. Many studies took aggregate energy demand as the measure of interest, rather than working in terms of the component fuels and considering cross-substitution, but some studies did disaggregate. Until the early 1980s, most authors assigned a GDP elasticity of about unity to developed countries and a higher one to developing countries. For example, Zilberfarb and Adams (1981) estimated an average elasticity of 1.35 for the latter category. The price elasticity of aggregate energy was usually estimated to be much smaller in magnitude for both developed and developing countries.

The authors tended to implicitly assume stable elasticity values by estimating functional forms leading to constant elasticities. However, later authors found large decreases over time in the GDP elasticity and associated them with changes brought about by the oil price crises of 1974-75 and 1979-80. Ramain (1986) surveyed OECD countries and reported far higher elasticities holding before 1974 than after it. For example, he gave pre-1974 values of 1.12 and .90 for Japan and the USA and post-1974 values of .34 and .40 respectively. Some other authors obtained similar results when they either split the time series into pre- and post-1974 and estimated conventional constant elasticities within the sub-periods, or fitted variable elasticity models over the whole period.

For Ireland, Conniffe and Scott (1990) found that applying a constant elasticity model to the data from 1960 to 1987 gave a GDP elasticity estimate of about 1.1, but with a poor fit and evidence of instability. Splitting the sample and using data from 1960-74 gave a GDP elasticity estimate of 1.3, while 1975-87 data yielded an estimate of .6. Fitting a model, permitting a variable elasticity, over the whole of the data led to the same results for the average elasticity during the periods and an even lower estimate of .5 for 1987. Disaggregating to individual fuels, the authors found that this phenomenon of decreasing elasticity occurred for the fuels, electricity, oil and LPG, but not for gas, coal and turf. However, natural gas only came on stream in the 1980s, so too much cannot be concluded about the stability of its elasticity, while neither coal nor turf showed any significant positive relationship at all with GDP growth over the whole data period.

This apparent evolution, for aggregate energy and important component fuels, from a state of being quite elastic with respect to GDP to being quite inelastic, would have great implications for energy policy formulation if the process could be assumed to have stabilised at the current elasticity values, or to be continuing in the same direction. However, the possibility that the elasticities might increase again, or that the decreases are somehow illusory, need to be considered.

3. Explanations for Apparent Elasticity Changes

Whether the decrease in GDP elasticity is accepted as real, or illusory, must depend, to an extent at least, on whether plausible causative mechanisms can be visualised to exist. To begin with, it is not implausible that the GDP elasticity may vary with the sectoral composition of an economy, since the energy intensity of economic growth may differ by sector. The Irish economy has evolved very considerably from 1960 to 1987 with the agricultural sector becoming steadily less important, relatively speaking, and first the manufacturing sector, and then the services sector, becoming more important. Indeed, even the early studies in the energy economics literature, as mentioned in the previous section, tended to assign lower elasticities to developed as compared to developing economies. But it seems unlikely that this explanation would be sufficient, on its own, to account for a drop in the Irish GDP elasticity from 1.3 to 0.5. Nor can it be easily applied to explain why a developed economy, such as that of the US, should show the decrease revealed by Ramain's previously quoted figures.

Other authors have argued that reduced elasticities are a consequence of technological advance and, in a sense at least, are actually disguised price effects. The chain of causation would be that the severe price hikes of 1973-74 and 1979-80 not only depressed demand at the time they occurred, but also triggered major research and development in energy efficient technology. This technology remained in place after prices fell again so that the increase in energy demand consequent on price reductions did not match the previous decrease when prices rose. Since the phenomenon is asymmetric with respect to price, econometric estimation does not catch it as a price effect and it appears instead as a seemingly irreversible decline in the GDP elasticity. Explanations on these lines of indirect or hidden price effects have been proposed by Wirl (1988) and Dargay (1990). In practice it does not matter if a decrease in the GDP elasticity is really a consequence of a past price rise triggering technical change, provided the new lower elasticity can be relied upon.

However, although some technical advances could conceivably have permanently lowered the GDP elasticity to some extent, the effects of other technical advances could also have led to serious underestimation of the GDP elasticity in post-price hike periods if conventional estimation methods were employed. To see this clearly, suppose that some years after a motivating price hike some highly significant technical advances are made and that these phase in over quite a long period, partly because of the time lag between motivation and discovery, but also because of the gradual phasing out of old equipment and introduction of new equipment embodying the advances. Suppose prices have stabilised and GDP has continued to grow, though perhaps not at a very high rate. If the technical advances have been great enough and phase in at an increasing rate up to some year, it is conceivable that energy use could be unchanged or even decreasing, so that an elasticity estimate based on this period could be zero or negative. However, once the technical advances had fully worked through, new GDP growth would require increased energy use and an elasticity estimated over a subsequent period would have become positive again.

The case just discussed is an exaggerated one, but shows how an overestimate of a reduction in elasticity is possible if the estimation period is still close enough to the price hike for the phasing-in effects to be still appreciable. Given that the Irish data employed for estimation ran to 1987, and that the second great energy price hike was 1979-80, the argument deserves consideration. It may be worth mentioning that other arguments are also possible that attribute apparent, but unstable, decreases in the GDP elasticity to hidden price effects. If it is not current price, but the expectation of future price, that motivates decisions to restrain energy consumption, it could be argued that decision makers did not take the initial price falls after the 1979-80 price hike as permanent, but expected the high prices to recur before long. The effect of this hidden variable of expected future price would not be attributed by econometric analysis to price, but might be manifested as an apparent decrease in the GDP elasticity. Of course, it would not persist after price expectations adjusted. The argument is perhaps less convincing than that based on technical advances, since energy demand is derived and high price expectations might reduce both GDP and energy, rather than affect the relationship between them.

The possibility that technical advances may be biasing estimates of elasticities, rather than truly lowering them, is connected to another problem: that of obtaining meaningful measures of energy. Equal volumes of a fuel in 1960 and 1987 could have corresponded to very different quantities of utilised energy, because the end use efficiency of appliances could have improved. It is possible that the relationship between the utilisable energy of a fuel, if that were observable, and GDP could be quite stable, even if that between a volume measure and GDP did not appear to be, during periods when technical advances leading to improvements in end use efficiency were taking place.

In the literature, relationships with aggregate energy have received most attention. However, aggregate energy is not as clear-cut a quantity as might be imagined. There are really a number of fuels, which can substitute for each other to varying degrees, and some procedure is required to produce an aggregate quantity. By far the most frequently used procedure is to form a weighted sum of quantities, where the weights are measures of the energy contents of the fuels in Joules, or British Thermal Units (BTUs), or ratios of the energy contents of other fuels to that of a "standard" fuel. The latter method can lead to a measure of aggregate energy as tonnes of oil equivalent (TOE). Energy price can then be calculated as total expenditure on fuels divided by this quantity measure. This amounts to a price per unit of energy content or unit of oil equivalent.

Criticisms of this type of aggregation have sometimes been made in the literature; for example, on the grounds that the theoretical energy contents of coal and electricity will not translate equally to availability for most users of the fuels. Thus Chern (1978), working with US aggregate energy, argued that weights should incorporate end use efficiency corrections. Factors such as versatility and convenience are not taken into account by weighting on energy content and other points could be made also. The point already made about individual fuels - that the end use efficiencies may have been improving over time - further complicates matters here if, as seems very plausible, the improvements occurred at different rates for different fuels.

The difficulty with incorporating end use efficiencies into the weighting process is that the relevant data are not available. The results of taking a small step in that direction will be mentioned in a later section. However, there are other approaches to aggregation too. If the derivation of an aggregate energy price is seen as a problem in index number construction of the type analysed by Allen (1975), or Diewert (1976), several methods are possible that ignore TOE or BTU. Very simple methods, for example, a Laspeyres index using base year weights, probably ignore too much information, but chained indices utilise the evolving composition by component fuels and might be argued to relate to a "price" of utilisable energy. Then dividing it into known aggregate expenditure should give a quantity interpretable, to a degree, as a measure of utilisable energy. The measure of aggregate energy is now a weighted sum of component fuels where the weights are functions of current and past relative fuel prices. The underlying idea is that if relative end use efficiencies vary over time, this should be reflected, to some extent at least, in varying relative prices.

Obviously, this cannot be a conclusive line of argument, since the equating of a quantity index to utilisable energy should not be pushed too far. But if analysis of such indices and their relationship to GDP led to different results than corresponding analyses of TOE measures, it would at least suggest that some of the diminishing GDP elasticity phenomena might lie in deficiencies in the energy measure. Interestingly, Nguyen (1987) claimed that conclusions about energy demand and the factors influencing it are sensitive to the aggregation method employed.

In the next three sections these possible explanations for the apparent decrease in GDP elasticity will be investigated further by analysing available Irish data. First though, some other explanations that have been suggested (and disputed) in the international literature need to be reviewed, if only to justify not examining them further. What the explanations have in common is a belief that relatively straightforward models and statistical estimates may be inappropriate in energy demand studies and that some complicated models and some sophisticated econometrics may reveal a different picture. However, the directions and details of the complications differ greatly from author to author.

The typical methodology of the original estimates of energy elasticities was to treat energy demand as a function of its price and GDP, usually assuming a log linear formulation and employing standard regression formulae. One theme of complication stayed within a single equation context and argued that extra variables should be incorporated, allowing for lagged effects of GDP, price and indeed of the dependent variable itself, to take care of adjustment effects, or other dynamic mechanisms. Also, it was argued that other possibly relevant variables should be included as well as technical change, even if only as proxied by a time trend. Examples in the literature include Beenstock and Willcocks (1981), Welsch (1989), Brennand and Walker (1990) and Bentzen and Engstead (1993).

Now undoubtedly the simple model is an approximation at best and lagged price effects are certainly plausible, although since prices are highly temporally related it is not evident why including several lagged price variables should give a much different long-run price elasticity, or have more effect on a GDP elasticity than just a single current price variable. The case for inclusion of other lagged variables and a time trend is much more dubious and has been criticised by authors including Kouris (1983) and Prosser (1985). It is true that models incorporating a large number of parameters can give better fits to data, in the sense of satisfying statistical criteria, than more parsimonious models, but even so, not every complicated model resulted in finding a stable GDP elasticity. The inclusion of many highly related variables sometimes led to difficulty in stating any clear-cut conclusions at all.

Other authors have complicated models in a different way by insisting that energy ought to be treated as just one of a set of commodities whose demands are simultaneously determined. Not only should multi-equation models be formulated, but systems estimation methods should be employed. Fiebig, Seale and Theil (1987) and Seale, Walker and Kim (1991) estimated consumer demand systems, with energy as one component, and claimed to find higher GDP elasticities than much of the literature has. However, the issue of time varying elasticities was not explicitly addressed, nor perhaps could it have been, given the data requirements for simultaneous estimation. Other authors have tried to take the simultaneous context even further. Longva, Oystein and Stern (1988) saw estimation in a general equilibrium framework as appropriate, where simultaneous effects of energy price changes on GDP could be allowed for. While simultaneous estimation is undoubtedly what should be done, if it could be, it usually cannot be, because of data deficiencies. Nor does it follow that simpler partial analyses have no evidential value.

4. Alternative Aggregate Energy Quantity and Price Measures

One way of assessing how the overall energy price has changed between the previous and current years would be to calculate the cost of the current year's consumption of fuels at both current and previous prices and look at the ratio. This is called a Paasche price index and the idea could obviously be extended to compare current price with that two years ago and so on to form a price index series. Each term uses the current, or most recent year's fuel quantities and makes no use of the fuel quantities in earlier years. However, a Paasche index could show the price change from t-1 to t by using the quantities for year t and another Paasche index could show the change from t-2 to t-1 by using the quantities for year t-1. The idea of chaining is that if overall price doubles between t-2 and t-1 and doubles again between t-1 and t, the deduction that price has multiplied by four between t-2 and t is arrived at by multiplying the two ratios. So a chained Paasche price index would compare current price with that two years ago by multiplying the two year-on-year indices. Extending this idea leads to a chained index series.

Other forms of price index are possible. For example, the fuel quantities for year t-1 could be costed at both year t and year t-1 to give a Laspeyres index measure of price change. A chained form of the Laspeyres index can also be derived and there are a variety of other possible indices also.

There are various arguments that can be made about the choice of a price index, but two simple points seem sufficient here. First, a chained index makes more use of the data than an unchained one, which ignores the prices and quantities in between the years being compared. Second, it has been found that in practice unchained Paasche, Laspeyres and Fisher indices can sometimes deviate considerably from each other, but the chained forms are much more uniform. They also tend to be close to other methods of obtaining indices that make intensive use of the data; for example, the discrete Divisia index.

Quantity indices can be defined analogously to price indices, but the easiest way to consider quantity indices is to remember that total current expenditure on fuels will be available each year. Dividing this by the relevant price will give a quantity measure. In the discussion that follows, most comparisons will be between a chained Paasche price index and the corresponding quantity measure, on the one hand, and the conventional TOE measures on the other. For convenience the index quantity measure will be described as a "Paasche" measure, although, strictly speaking, the result of dividing expenditure by a chained Paasche price index is a chained Laspeyres quantity index. Findings from other indices will be discussed in the Appendix to show that any other set of chained indices would have given similar results.

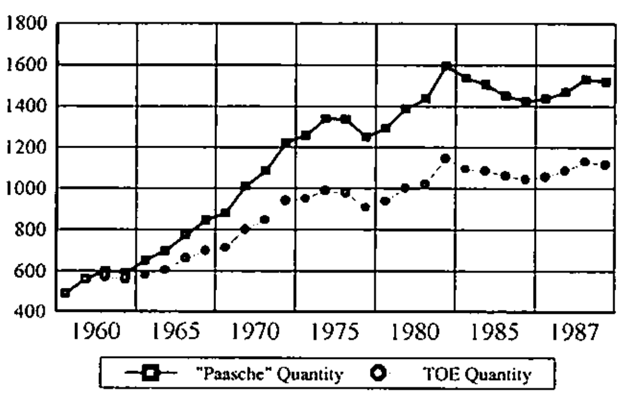
The data employed to construct the indices are the same as employed by Conniffe and Scott (1990) in their study based on TOE measures and consist of quantities and prices of the six fuels - piped gas, bottled gas (LPG), electricity, coal, turf and oil - for the years 1960 to 1987 inclusive. Prices were deflated using the GDP deflator and quantities excluded any amounts used to manufacture other fuels. Some more recent data have become available, but these will be employed in the final section of the paper for purposes of verification rather than estimation.

Indices versus TOE Measures

The index and TOE quantity measures are compared graphically in Figure 6.1 where they have been scaled to have the same value (100) in 1960. The chained Paasche quantity rose above the TOE measure and diverged increasingly from it. The index quantity measure would show a much higher energy consumption in 1987 than the TOE measure would and indeed would suggest that the rate of increase in energy consumption has not fallen off as much (compared to the pre-1974 rate) as the TOE measure would seem to indicate. The pattern is perhaps compatible with an interpretation of the index quantity as closer to utilisable energy than is the TOE aggregate.

Figure 6.1

Quantity Measures Compared

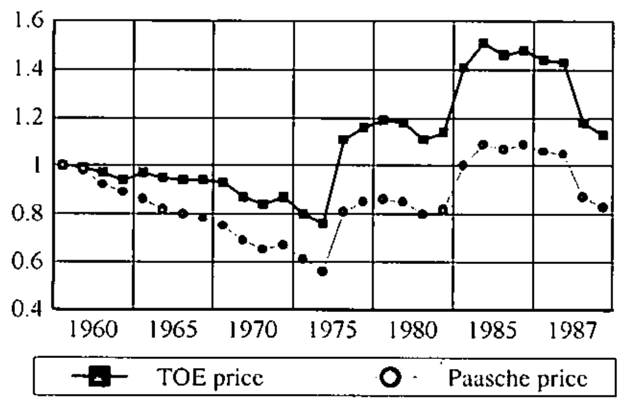


The chained Paasche price index and the price per unit of TOE (again scaled to be equal in 1960) are shown in Figure 6.2. Here the situation is almost the reverse of that for quantities; the price index is below the TOE price for the whole period after the initial two years. Of course, this could have been logically deduced from the fact that the product of the price index and quantity index is real expenditure. Note that the differences between the two series are greatest in the years immediately after the price hikes of 74-75 and 79-80.

If the identification of the index quantity with accessible or utilisable energy could be taken as valid, Figure 6.2 would indicate that the price of utilisable energy has not risen over the period to the extent the TOE price would indicate. In fact the index energy price was slightly lower in 1987 than in 1960. Note that prices, being deflated, are expressed in real terms. The implication would be that improvements to end use efficiencies of fuels at least compensated for the price rises. While the TOE price is undoubtedly a valid measure of the cost of a unit of TOE, it seems to overestimate true energy cost in that it makes no allowance for improved end use efficiency.

Figure 6.2

Price Measures Compared



Using exactly the same econometric analysis as Conniffe and Scott (1990) employed for the TOE measures gave a considerably higher price elasticity for the indices; the value being about -0.6, or 50 per cent higher than that for the TOE measures. However, there was still evidence that a constant GDP elasticity model did not adequately fit the data and that a decreasing elasticity formulation provided a better fit. But the rate of decrease was not as large as with the TOE estimates. Details of the econometric tests and diagnostics employed have been given in Conniffe (1991) along with accounts of modifications to the basic model incorporating lagged price effects. Lag patterns are more clearly identifiable with the index measures than was the case with TOE, although the long-run price elasticity was relatively unaffected by the lag structure, as is to be expected given the autocorrelation of prices.

The persistence of the indications of a diminishing GDP elasticity may be partly because other explanations may be involved, besides that of the identification of some measure with utilisable energy; for example, sectoral evolution of the economy. But it could also be because the Paasche measure is not an adequate approximation to utilisable energy. It would be wrong to claim that relative prices are precisely proportional to relative efficiencies. Price is affected by properties of fuels, such as convenience and cleanliness, besides utilisation efficiencies. The quantity index is not truly a measure of utilisable energy, although it may be closer to it than is the TOE measure. The findings from analyses of the indices cannot be taken as more than suggestive.

A Very Restricted Direct Adjustment for End-Use Efficiency

Measures of end-use efficiencies of fuels for all of the years 1960 to 1987 are not currently available. But Scott (1992) has given estimates of end use efficiencies for the year 1987, which are shown in Table 6.1. Since end use efficiencies of at least some fuels have certainly been changing over the period, the results of weighting the fuel TOE contents by their 1987 end use efficiencies before summing to get the quantity measure will be far from an ideal measure of utilisable energy, but at least it will differ from the TOE one.

Having calculated this efficiency adjusted energy (EAE) measure, a corresponding price can be obtained by dividing total expenditure on fuels by the measure. In Figure 6.3 this price is compared with the TOE and Paasche index prices, again scaling to equality in 1960. The price of EAE stays between the other two prices, but remains closer to the TOE price.

In the case of the quantity measure, it is clear that since the efficiencies in Table 6.1 were all less than unity, EAE in any year would have to be less than the TOE quantity measure. However, when rescaled to equality for 1960, which is reasonable since for elasticity estimation it is changes over time that matter, the quantity measure was found to lie between the index and TOE measures previously shown in Figure 6.1. Again, the EAE measure remained closer to TOE than to the index.

The price and GDP elasticities estimated using the EAE measures are quite similar to those obtained from the TOE measures. The price elasticity is slightly higher (though not statistically significantly so) than the TOE estimate, but well below the index estimate. There is not as great an apparent reduction in the GDP elasticity as in the TOE case, but more than for the index. It could perhaps be hypothesised that the EAE measure takes up some of the discrepancy between TOE and true utilisable energy, but not as much as the index does.

Figure 6.3

Evolution of Energy Prices over Time

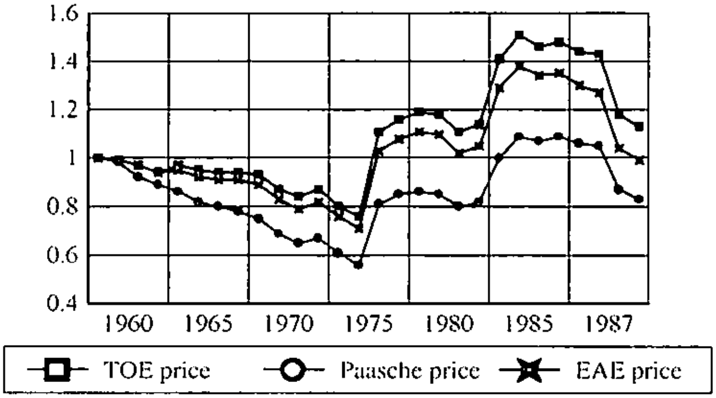


Table 6.1: *End-Use Efficiencies for Fuels, 1987*

Fuel	*End-Use Efficiency (proportion)**
Gas	0.78
Electricity	0.72
Coal	0.44
Turf	0.34
Oil	0.45
LPG	0.67

* These figures were derived by first estimating end-use efficiencies by sector - residential, industrial, transportation, commercial - for each fuel and then weighting by the relative importance of the sectors.

5. Adding Measures of Structural Change

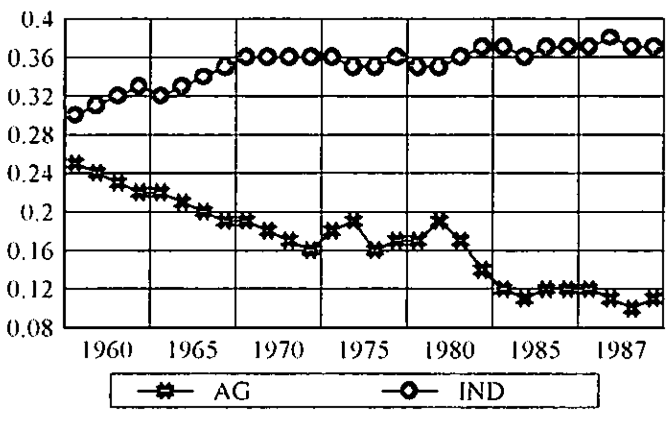
As already mentioned, the Irish economy has evolved very considerably over the period 1960-1987 and it is possible that as sectors of the economy changed in importance the aggregate GDP elasticity could change also. The implication here is that the elasticities of energy demand with respect to sectoral output might differ by sector. Then, even if elasticities were constant over time within sectors, the aggregate elasticity could still change with time.

Clearly the direct and best way of investigating this, if fully satisfactory data existed for all sectors, would be to estimate output elasticities for different sectors and compare them. Unfortunately, fully comprehensive data are only being assembled, so this is not yet a feasible approach for all sectors. The alternative, which will be pursued, is to add measures of the evolutionary state of the economy into the aggregate model and see if the GDP elasticity is affected by them. Since a regression coefficient can be interpreted as measuring the response to an explanatory variable given that other variables in the model are held constant, it should, in principle at least, be possible to deduce what the GDP elasticity would have been if the economy had not evolved structurally, although some imprecision will inevitably result from multicollinearity between the structural variables and GDP.

The two variables taken as measuring changing economic structures are the proportion of GDP accounted for by Agriculture, Forestry and Fishing and the proportion accounted for by Industry. The first measure, to be denoted by AG, declined over the period from about 25 per cent in 1960 to 11 per cent in 1987. Apart from slight fluctuations in the 1970s the decline was continuous. The second variable, to be denoted IND, increased from 30 per cent in 1960 to 36 per cent by 1968 and then fluctuated a little (touching 38 per cent in 1985) subsequently. The Services sector filled the percentage gap created by the continuing decline of AG from 1968 on. The evolution of the variables is shown in Figure 6.4.

Figure 6.4

Evolution of Measures of Sectoral Structure



Commencing with the TOE quantity and price measures, adding AG to the model had negligible effects on elasticities, nor was the variable itself statistically significant. The IND variable was closer to statistical significance, but did not achieve it. It may be worth mentioning that although the effects on the GDP elasticity estimate were infinitesimal, there was a substantial reduction in the t values. This is because AG and IND are highly correlated with real GDP, the correlations being -.94 and .83 respectively. More detailed information about these analyses, including accounts of the econometric formulations and tests, are given in Conniffe (1992).

Repeating the process for the EAE variables gave very similar results to those obtained for the TOE measures. Continuing to the Paasche index measures the sectoral change variables came closer to achieving statistical significance and actually do so in some of the variants with lagged price structures. The best model - in the sense of showing the largest effects for AG and IND - is one with the price effect represented as a five period, second order, distributed lag. The elasticity estimates and sectoral change coefficients are shown in Table 6.2.

Table 6.2: *Adding Structural Change Variables to the Model*

Model	*Price Elasticity*[1]	*GDP Elasticity*	*AG Coef.*	*IND Coef.*
P, GDP	-0.64	1.20 (28.1)[2]		
P, GDP, AG	-0.78	.99 (11.6)	-.26 (-2.8)	
P, GDP, IND	-0.62	1.06 (18.5)		.98 (3.2)
P, GDP, AG, IND	-0.71	.97 (12.3)	-.16 (-1.6)	.73 (2.2)

[1] Long-Run Elasticities [2] t values in brackets

The IND variable is highly statistically significant and the pair of variables are certainly jointly significant when entered together. The IND variable is the most statistically significant, probably partly because of the lower magnitude of its correlation with GDP. The proportion of Industry in GDP rose in the early years of the period and it is plausible that energy demand was affected by this. Without sectoral change variables in the model, this effect would be attributed totally to GDP growth. It could be argued that perhaps it should be, since the sectoral change and GDP growth were far from independent factors. However, what is important for predicting future energy demand is the GDP elasticity that holds currently and the output of the industrial sector has been a relatively constant proportion of GDP since the end of the 1960s. So it could make sense to delete out the contribution of sectoral change, or at least that attributable to industry share. Another way of looking at this is to say that if effects of sectoral change were included as GDP growth effects, there would have been a higher GDP elasticity in the earlier part of the period. However, the difference is about .2 at most.

An obvious question now arising is if there is any longer any evidence of a declining GDP elasticity given a model that has allowed for sectoral evolution and perhaps even the improved end-use efficiency of fuels, in so far as the latter can be assumed partially catered for by working with a Paasche price and corresponding quantity index. A statistical test for decreasing elasticity (based on generating a new variable consisting of the product of the log of GDP multiplied by a time trend, adding it to the model and applying a test to its estimated coefficient) led to a t value of -1.84. This falls short of statistical significance, but it is still suspiciously close to significance. Also, the model with the sectoral change variables, lagged price variables and the new variable constructed from the product of a time trend and GDP, now contains substantial multicollinearity, which depresses t values. It seems sounder to proceed by accepting the decrease and estimating its magnitude for the whole 1960 to 1981 period. This turns out to be .16, plus or minus an error estimate. But even taking it as .2 and allowing another .2 for sectoral evolution, the overall reduction is not nearly as large as the initial TOE analysis would have suggested. A 1987 elasticity of about .9 rather than .5 would seem indicated.

However, it should be repeated that a lot depends on the identification of the Paasche index variables as meaningful measures of quantity and price. Not only do the index measures lead to a more stable relationship, but the measures of sectoral composition had far less explanatory power with the TOE measures. It could be argued that since energy will actually be purchased as quantities of fuels, which can be thought of in TOE terms, it is really TOE elasticities that are important for policy decisions. This is a valid argument and the justification for the relevance of elasticities based on the index must be that they would become applicable to TOE quantities if conditions stabilised. To repeat arguments: the idea is that utilisable energy increases in line with GDP in a relatively stable fashion; utilisable energy is a fixed proportion of TOE, given a constant technology, but not when end use efficiencies are actually changing; so when changes have worked through, the elasticities will coincide again.

6. Modelling TOE Energy with Irreversible Price Effects

From the concluding remarks of the last section it is clear that an analysis of TOE energy in terms of GDP, price and end use efficiency would be desirable. The problem is that the measures of end use efficiency are not available. The approach of previous sections was to replace TOE by an index. But instead, perhaps some proxy for the missing variable could be found. Utilisable energy is the product of TOE and the missing variable. So, working with the conventional log model, and assuming that utilisable energy has a stable relationship with price and GDP gives

$$\text{Log } q_t = x_t + b \log p_t + d \log y_t$$

where q, p and y denote TOE, its price and GDP respectively and x_t is a variable representing the deviation between TOE and utilisable energy which varies with technical change. Lagged price effects could be included, although, as before, the high correlations of p_t and p_{t-1} suggest that neither the estimate of the long run price elasticity nor that of the GDP elasticity will be sensitive to the precise lag structure. This model differs from the standard regression one in that x is not a fixed intercept, but variable. Since x is not observable, it must itself be modelled. Price hikes are presumed to trigger research, followed after a lag by technical advance, which remains in place when prices fall. This suggests relating x to the cumulative total of (log) price increases, where price decreases are omitted from the total. This cumulative price increase variable is

$$C_t = \sum_{i=1}^{t} \Delta(\log p_i) h_i$$

where h_i is unity if Δ is positive and zero otherwise and its development over time is shown in Figure 6.5.

In formulating a model, x_t could be taken as approximately a linear function of C_{t-m}, where m represents the lag between research and discovery. This suggests that a model

$$\log q_t = a + b \log p_t + g \log C_{t-m} + d \log y_t$$

might be appropriate for TOE energy data. Of course, lagged values of C_{t-m} could also be included, although the same remarks as made about lagged price variables would apply. In this model the b coefficient measures the usual, reversible, price elasticity, while the g coefficient measures the price induced, but irreversible, technical change effect. This approach to handling the direct and indirect effects of energy price is derived from the "ratchet models" of Wolffrom (1971) for asymmetric price responses, which have been applied by Young (1983) to modelling addictive behaviour and, indeed, by Young, Stevens and Wills (1983) to a study of residential electricity demand.

As so far formulated, the model would correspond to a stable GDP elasticity. Some technical advances may not take effect though improving the end-use efficiencies of fuels, but could conceivably permanently reduce the GDP elasticity. The C variable can also be used to specify models with a varying GDP elasticity, by adding a term of the form

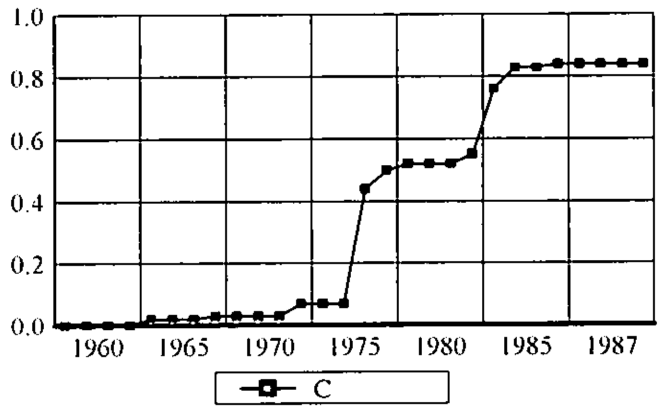
$$k \ (C_{t-r} \ \log \ y_t \ )$$

into the model. The term would modify the elasticity d by k C_{t-y} and would reduce it if k is negative and if C_{t-r} increases due to a price rise. Here r again represents a lag between price rise and subsequent effect on the elasticity. If there are different types of technical advances, there seems no reason why r should equal m. By estimating the coefficient k and testing its significance, the hypothesis of a decreasing rather than a stable GDP elasticity can be examined.

In fitting the model with the reversible and irreversible price effects, a value of m = 2 was found appropriate and the estimates of b, g and d were -.2, -.3 and 1.2 respectively, with corresponding t values of -3.0, -4.4 and 22.0. More detailed descriptions of the econometric issues involved and the estimation methods chosen are provided in Conniffe (1993). The price elasticity of -.2 is smaller than other analysis methods yielded, but these did not allow for the irreversible price effect, which is larger in magnitude. Diagnostic tests, based on examination of residuals, did not seriously undermine the plausibility of the model. Introducing the product term already mentioned, a formal test for a diminishing GDP elasticity led to a value for k of -.06 (with r = 3) and a t value of -1.3, which falls well short of statistical significance.

Figure 6.5

Cumulative (Log) Price Increases



So it seems that using the idea of irreversible as well as reversible price effects, a model can be estimated that satisfies the statistical criteria for plausibility without requiring the addition of any mechanism to permit a decreasing GDP elasticity. It would be going too far to claim that the model formulated in this section is the true one; there might be other ways of incorporating irreversible price effects also. But the analysis reinforces the findings of earlier sections that the apparent diminishing GDP elasticity may be, to a large extent, a reflection of other unmeasured factors.

7. Seeking Confirmatory Data

The original Conniffe and Scott (1990) estimates, as well as the similar findings in the international literature, suggested that the GDP elasticity applicable to Irish energy demand in 1987 had fallen to about .5. The re-examination of this paper suggests the elasticity is much higher. Now further data ought to help confirm matters. A theme running through the previous section has been that technical advances motivated originally by the price hikes of 1973-74 and 1979-80 have been upsetting the proportionality between utilisable energy and TOE and distorting elasticity estimation. However, when technical advances have worked through the proportionality should be restored and estimates incorporating the new data should show the GDP elasticity increasing again.

The data on which all the analyses presented were based terminated at 1987. Scott (1993) has recently extended the data to 1991. The various estimates could be recalculated using all the data, or the estimates already obtained could be compared with the actual outcomes over the period 1988-91. There is always some virtue in keeping estimation data separate from validation data in trying to arrive at objective assessments. The validation period is rather short and perhaps not distant enough from the 1979-1980 price crisis to be sure that consequent technical changes have fully worked through. However, the postulated effect should be observable.

From 1988 to 1991 real GDP increased by 14 per cent while TOE energy consumption increased by 10.2 per cent. However, this lower increase is at least partly due to the increase in energy price per unit of TOE over the period, measured in real terms, using the GDP deflator. The prices of two fuels, electricity and peat, actually fell by about 5.5 per cent, but the prices of coal, oil, LPG and gas rose by 8.5, 7.5, 10.8 and 12.7 per cent, respectively. The overall TOE price, in which oil has the heaviest weighting by far, rose by 6.5 per cent. Energy demand is price inelastic, but even so, estimates of around -0.4 would imply that this price rise caused a downward adjustment of 2.6 per cent on energy demand. Adding this to the observed increase of 10.2 per cent in TOE energy consumption implies that, had price remained constant, the increase would have been nearly 13 per cent. Comparing this with the 14.1 per cent increase in GDP, and allowing for inevitable data variations, suggests it would be unwise to take the current GDP elasticity as much below unity and certainly not as low as .5.

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APPENDIX 6.A: The Various Price Indices

The simple Paasche price index for change from a base year to year t uses the fuel quantities in year t as weights. So

$$(PA)_{0t} = \frac{\sum P_{ti}Q_{ti}}{\sum P_{0i}Q_{ti}} \quad i = 1, 2, \dots 6$$

where the summation is over the six fuels. The Chained Paasche index for year zero to year one is the same as the simple index. The chained index for year zero to year two is the product of the two simple indices for year zero to year one, and for year one to year two. Unlike a simple index, which uses final year quantities as weights in all year values, the chained index uses the intermediate quantities also. As formulae

$$(CPA)_{01} = (PA)_{01}, (CPA)_{02} = (CPA)_{01}\,(PA)_{12}, (CPA)_{03} = (CPA)_{02}\,(PA)_{23} \text{ etc.}$$

Laspeyres price and chained price indices can be defined similarly, the difference being that the link from period k to k+1 uses the quantities for period k. For example,

$$(L)_{01} = \frac{\sum P_{1i}Q_{0i}}{\sum P_{0i}Q_{0i}} \quad i = 1, 2, \dots 6$$

The simple Fisher index is defined as the square root of the product of the simple Paasche and Laspeyres indices, and a Chained Fisher index can be defined by

$$(CF)_{01} = (F)_{01}, (CF)_{02} = (CF)_{01}\,F_{12}, (CF)_{03} = (CF)_{02}\,F_{23} \text{ etc.}$$

The Divisia index originates with a treatment of time as a continuous variable leading to an expression for an index in terms of integrals over time. The approach was developed by Divisia (1925) and Roy (1927). Allen (1975, p. 181) points out that any of the chained indices can be regarded as discrete approximations to the underlying continuous index. Another discrete approximation is that due to Tornqvist (1936), for which the price index for periods 1 to 2, say, is

$$(D)_{12} = \text{Exp}[\tfrac{1}{2}\Sigma(W_{i2} + W_{i1}) \log(P_{i2}/P_{i1})],$$

where W_i denotes the budget share

$$P_i\,Q_i/\Sigma P_i\,Q_i\,.$$

Quantity indices could be defined in a similar way to price indices by weighting quantities by base year prices (the simple Laspeyres measure), or by current year prices (the simple Paasche measure) and the extensions to Fisher type indices and chained indices follow in the same way as for price indices. Quantity indices can also be obtained by just dividing expenditures by price indices and this has some virtues as will be returned to shortly. The various measures of price and quantity are not all independent. For example, it is easily verified that dividing expenditure by a Paasche price index actually gives a Laspeyres quantity index.

As regards choice of best indices, guidelines can be drawn from both statistical and theoretical economic considerations. Fisher (1922) set out a set of desirable statistical properties that index numbers ought to display: such as identity, proportionality and change of units invariance. Some properties are satisfied by all the indices mentioned earlier and some are satisfied by only a subset of them. For example, the factor-reversal property is that the product of a price index and a quantity index should give the corresponding ratio of expenditures. Although satisfied by the Fisher-Ideal index (which, as the name suggests, satisfies most of Fisher's criteria), this is not satisfied by simple Laspeyres or Paasche indices. However, there is no reason why a quantity index should not be Laspeyres and a price index Paasche and the property is then satisfied by just generating either the price or quantity index by formulae and obtaining the other by dividing into current expenditure.

The "theoretical" economic arguments for or against particular index number formulae may not be very relevant to the situation of determining an aggregate energy quantity and price from individual fuels. They arise from considering the index formula as an approximation to an unknown (but assumed constant over time) "true" aggregator. The nature of the approximation may, in some applications, be inconsistent with what economic theory may suggest for the situation. For example, a simple Laspeyres quantity index could be written

$$\frac{1}{E_0}\sum P_{i0}Q_{it}$$

so that the weights Pio/Eo (Eo being expenditure in the base year) are constant for all years and the index is thus a constant linear function of the component quantities (fuels in this case). It is this linearity that is sometimes deemed inconsistent with economic theory. If, for example, the Qi referred to inputs to a sector of industry and the indices were to represent output quantity and price, the linear formulation might be thought to imply a rather restrictive concept of the sector's production function. The Fisher Ideal or Divisia formulae, which do not reduce to linear forms, might be considered less constraining. This topic is discussed by Diewert (1976) and, in the agricultural context, by Boyle (1986-87). However, these remarks do not apply to chained indices in any event, because then the weighting formula is evolving with the observations.

As was mentioned in the main text, it has been found in practice that the various chained indices and Divisia index behave very similarly; something that need not be true of the simple indices. So the chained Paasche price index was by no means the only candidate for use and it would be worrying if the findings described were very dependent on the precise formulation of the measures of quantity and price. In fact, they were relatively invariant over three other indices: Chained Laspeyres, Chained Fisher and Divisia. This is illustrated in the table where all four indices are compared with each other and with the TOE measures in terms of the coefficients of variation of quantity and price measures.

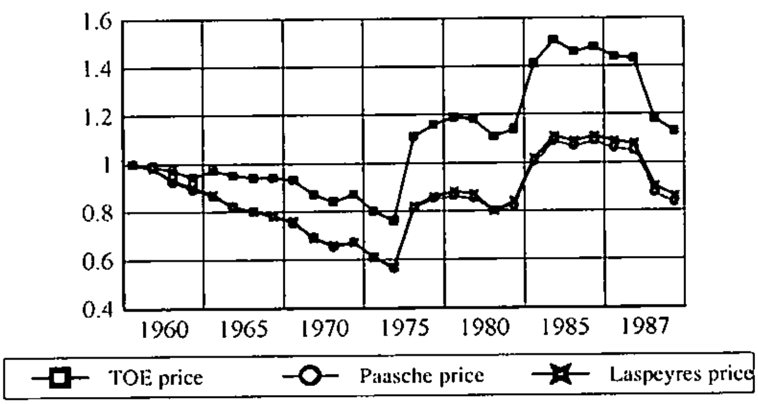
It is clear that the major difference in the Table 6A is between TOE measures and the others. The index measures all show a greater coefficient of variation of the aggregate quantity measure and a smaller coefficient of variation of the price measure. The differences between indices are very slight. Finally, the Figure 6A shows the Chained Paasche and Laspeyres price indices as compared to the TOE price. Again, the dominant differences are between the two chained indices and the TOE measure.

Table 6A: *Comparison of Indices in terms of Variation in Quantity and Price*

Measures of Quantity and Price	*CV of Quantity*	*CV of Price*
TOE	24	21
Chained Paasche	32	17
Chained Laspeyres	31	18
Chained Fisher	31	17
Divisia	31	17

Figure 6A

Paasche, Laspeyres and TOE prices



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