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ENERGY DEMAND IN IRELAND, PROJECTIONS AND POLICY ISSUES

S. SCOTT

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GLOSSARY OF TERMS

MTOE:	Million Tonnes of Oil Equivalent 1 TOE = 10^7 Kilocalories = 41.868 gigajoules = 11.63 Mwh = 397 therms
LPG:	Liquid petroleum gas ("bottle gas")
Energy intensiveness:	energy required per unit of output
Elasticity:	responsiveness to a change, e.g., the price elasticity of demand is the percentage change in demand resulting from a one per cent change in price.
CPI:	Consumer Price Index
CSO:	Central Statistics Office
EDM:	Energy Demand Model
Relative price or real price:	the price relative to the Consumer Price Index for All Items.
ln:	Natural logarithm or log to the base e

INTRODUCTION

This paper has two aims. First, it presents projections of energy demand to 1990 which emerge from an analysis of data on past energy consumption. These projections must be viewed as just one contribution to a set of forecasts which should be made using a variety of approaches. Secondly, it discusses the role of energy pricing as part of an energy policy.

In the first chapter some background information is presented on total consumption and final deliveries of fuels from 1950 to the present day.

The second chapter presents an analysis of the data. This produces a wide range of projections of energy demand depending on assumptions made concerning the time paths of GDP and energy price and on the ways in which energy consumption responds to these. Energy price emerges as a small but significant factor influencing demand in the short run. However, in the longer term this influence increases.

The third chapter contrasts these projections with the official projections made by the Department of Industry, Commerce and Energy (1978), the latter being somewhat higher and shortly to be revised, and looks at them both within the context of experience in other countries.

Chapter four discusses some of the issues raised in the foregoing chapters. In particular it discusses aspects of energy pricing as part of an energy policy. It concludes that current lack of recognition of the importance of pricing causes price structures to exist which help to undo some of the effort put into energy saving programmes in recent years.

Chapter 1

BACKGROUND INFORMATION

Ireland's Energy Consumption since 1950

Since 1950, energy consumption has more than doubled. This applies both to total energy and to energy deliveries, as can be seen from the graph in Figure 1. By the term "deliveries" is meant all fuels which go to the final consumer for use in heating and lighting and so on, excluding deliveries of fuels for conversion to some secondary fuel. The trend displays three main phases: instability from 1950 to 1958, a rise from 1958 to 1973, and unsteady growth after 1973. It will be useful to look at each of these phases in turn with the help of two measures of the relative price of energy (that is, the price of energy adjusted for general inflation) and of the time path of GDP since 1950, given in the lower part of Figure 1.

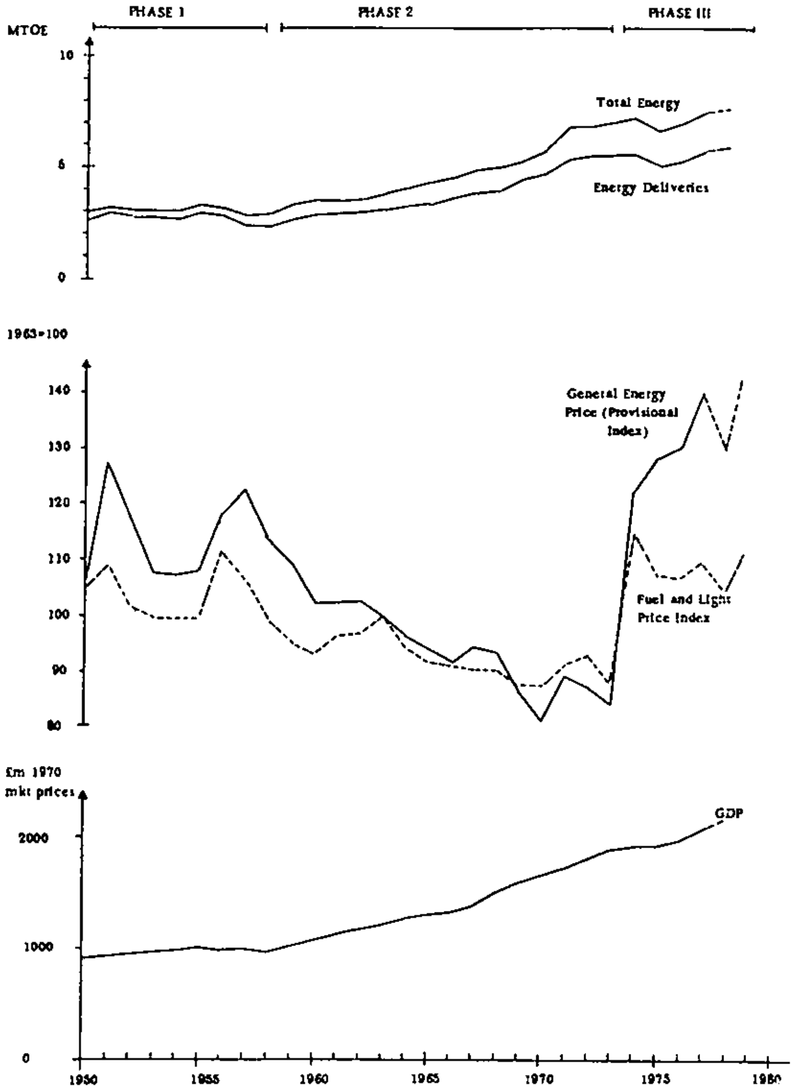
In the first phase of final deliveries up to 1958, energy consumption fluctuates around the two and a half MTOE level. Within this period, 1950/51 was a very cold winter, 1955 witnessed a relatively high GDP growth and 1956/57 saw the Suez crisis and consequent rise in fuel prices. The GDP stagnation of 1956 to 1958 contributed to the low total deliveries in the final years of this phase.

The second phase from 1958 to 1973 shows a steady growth at an average compound rate of 5.8 per cent per year, such that by 1973 final deliveries approached two and a half times the 1958 level.

This leaves the third phase, from 1973 to the present, featuring the dramatic price rises of 1973/74 and 1979, and the recession of 1975/76.

The three phases of energy consumption more or less echo that of GDP, as is to be expected, and in the middle phase

Figure 1. Energy Consumption, Indices of the relative price of energy, and GDP 1950-1978.



Sources

Total Energy, Energy Deliveries, General Energy Price, Fuel And Light Price; as in columns (1), (2), (8) and (9) of Appendix 1. Figures for 1979 are estimates except for the Fuel and Light price index.
GDP: National Income and Expenditure 1967, Table 86, and 1975 Table A6 for Expenditure on GDP.

deliveries grow faster than GDP overall. The phases are also fairly consistent with the trend in prices, which similarly displays three phases in reverse image: a high phase, followed by a decline, followed by a high phase again. In other words, one can discern from the graphs a consistent relationship between final deliveries of fuels, on the one hand, and GDP and fuel price on the other. GDP and price are likely to be important factors influencing fuel demand, though not the only factors, as we shall discuss later. Now we will turn our attention to the paths of the individual fuels which make up energy deliveries.

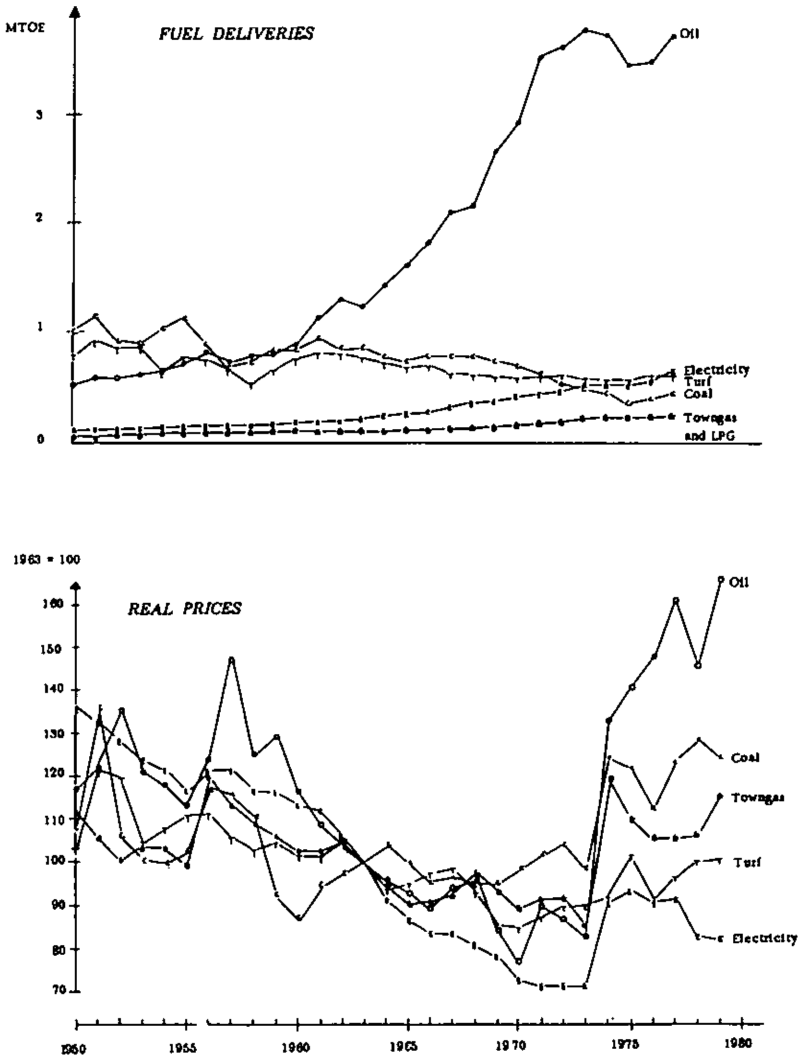
Final Deliveries of Individual Fuels

Information on individual fuels is summarised in Figure 2 which shows the paths of fuel deliveries and of individual fuel prices over the period since 1950. The data have some shortcomings and have yet to be formally analysed. However, they were considered to be worth presenting here in diagramatic form.

The fuel showing outstanding growth is obviously oil. The rise of oil consumption is accompanied by considerable declines in coal and to a lesser extent turf, which two initially constituted three-quarters of final deliveries. The oil price rise relative to consumer prices in general, following the Suez crisis, and the coal and turf relative price declines of the next few years saw a halt in the growth of oil consumption and a temporary reversal of the decline in consumption of coal and turf. In turn, coal and turf appear to compete with each other.

The rise in the usage of oil seems hardly surprising when one looks at price movements; between 1959 and 1973 the price of oil relative to consumer prices declined by over 30 per cent in contrast to the relative prices of coal and turf which rose by six per cent and declined by 14 per cent respectively. The price of oil relative to the price of other fuels combined fell by some 25 per cent. A more important reason may be that the use of solid fuels, requiring a person to stoke and remove ash, was most hit by labour costs, since hourly earnings rose by 84 per cent relative to consumer prices during this phase (in fact data till 1963 cover weekly earnings

Figure 2: Deliveries and indices of the relative prices of individual fuels, 1950-1978



Sources: Fuel deliveries: as in column (2) of Appendix 1, see notes.
Indices of fuel prices: as in column (9) of Appendix 1.

Notes: The price index for each fuel is expressed relative to the CPI and not directly relative to each other. Readers interested in the price of a fuel relative to other fuels might consult Appendix 8 for a table showing costs per unit of useful heat. Figures for 1979 and some for 1978 are provisional.

only). This would have imposed an increasing addition to the cost of using solid fuel. Since 1973, on the other hand, the price of turf has risen less than that of other fuels (except LPG or bottle gas, not shown) and turf's share has risen accordingly.

Electricity's share since 1950 has grown from about three per cent of final deliveries to over 11 per cent by 1977. It too supplanted the labour intensive fuels for the reasons outlined above, especially as its relative price decline during the 1960s was even more spectacular than that of oil. This relative price decline of about 36 per cent reflects technological improvements in the efficiency of electricity generation as well as declines in feedstock prices. Furthermore, since 1973 the price of electricity has risen relatively less than that of other fuels (except turf and LPG) because fuel costs are less than 50 per cent of total costs and prices are consequently cushioned against any extreme fuel price movements. Also with 25 per cent of electricity being generated from turf, electricity users have recently benefited from the fact that turf prices are pegged artificially low, a point discussed in the final chapter.

Final deliveries of towngas have been fairly constant overall. Meanwhile LPG, starting from a small base, has doubled its deliveries since 1970. Towngas and LPG, combined, now account for about four per cent of final deliveries and are equivalent to some 35 per cent of final deliveries of electricity.

To summarise then, since 1950 we have seen a decline in the share of labour intensive fuels, turf and coal, and a rise in the share of non-labour intensive fuels, oil, electricity and the combined gases. Reversals of the trends occurred recently in the cases of oil, turf and coal, probably for reasons of price, be it the price of the fuels themselves or indirectly, in the cases of labour intensive fuels, the deceleration in the rise of the price of labour relative to energy price. Apart from some obvious uses, such as lighting, the fuel deliveries diagram would suggest that a reasonable degree of substitution between fuels can and does take place.

Having discussed the background information in broad terms, we will now analyse the data to see what relationships emerge and what projections they give.

Chapter 2

ANALYSIS OF ENERGY DEMAND AND PROJECTIONS TO 1990

In this chapter we start with a brief outline of the analysis of the data covering the period 1958 to 1977. We then present projections of energy demand in 1990 based on certain assumptions. Details of the analysis are given in Appendix 2.

Basically our task is to construct a model which gives a relationship between energy consumption and the items which affect energy consumption. We know that in theory, price will affect the quantity of a good consumed. It is clear that income, or GDP, also exerts a strong influence on energy consumption. It is also realistic to assume that responses to changes in energy price take a while to materialise. Using statistical criteria, the results lend some support to this simplified assumption about behaviour.

The results of the analysis provide us with estimates of the responsiveness of energy consumption to price. We find that, in the short run, a one per cent rise in the relative price of energy results in a 0.3 per cent decline in energy consumption approximately. In the long run, however, when all the responses are played out, there is a 0.7 per cent or 0.8 per cent reduction in energy consumption, in all. After about one and a half years, roughly 50 per cent of the response has taken effect.

We will now examine the projections of energy consumption to 1990, which emerge from the foregoing analysis.

Projections from the Models

Projections to 1990 are made for four situations of GDP and energy price. These situations are summarised in the following table under the headings Case I to Case IV.

Table 1: *Four alternative assumptions for GDP and energy price in 1990*

	Case I	*Case II*	*Case III*	*Case IV*
1977-90 Growth in GDP (%)	70	70	70	100
Implied annual GDP growth, (%)	4.17	4.17	4.17	5.48
1977-90 Growth in price of energy relative to consumer prices, (%)	0	20	50	20
Implied annual relative price rise (%)	0	1.41	3.17	1.41

The average rate of growth in GDP having averaged about four per cent for the last decade or so, a fairly likely situation might lie around Case II. It should be noted that the price rises refer to the Fuel and Light price index deflated by the All Items index, and that over 1973/74 this relative price rise amounted to 31 per cent. It should also be noted that GDP itself is not unaffected by changes in energy price but this is not allowed for here. A population forecast of 3.63 million is used for 1990, based on Keating (1977). The recent population revision may cause us to raise this forecast.

Energy consumption in 1977 was 7.5 MTOE. The following table gives a summary of the projections. Full results are shown in Appendix 5.

Table 2: *Projections of total primary energy demand in 1990, MTOE*

Functional form	*Case I*	*Case II*	*Case III*	*Case IV*
(a) All variables* in log form	15.44	13.93	12.28	17.65
(b) Energy and GDP in log form	15.52	13.71	11.45	17.39
(c) GDP in log form	12.43	11.57	10.34	13.21

*Energy, GDP and price.

In addition to showing projections for the four cases or combinations of GDP and energy price, Table 2 gives the results from three functional forms. The use of any functional form involves making implicit assumptions about the behaviour of future responsiveness of energy consumption to changes in GDP and price. In Table 2, in line (a), the functional form chosen implies no change in responsiveness from that generally prevailing in the period 1958-1977. This would seem unlikely. The functional form in (b) implies an increasing responsiveness of energy consumption to price changes. The functional form chosen in (c) implies a declining responsiveness of energy consumption to GDP growth. The functional forms in (b) and (c) seem reasonable.

The divergence between the figures is quite large. It is a salutory reminder of how one's implied assumptions can influence the results.

Summary of Analysis

These models are an attempt to extract as much information as possible out of existing time-series data, such as it is. We find that while energy consumption is strongly influenced by GDP it is also affected by price, especially when one allows for a time lag in the response. The evidence suggests that in the long-run, a 10 per cent rise results in a 7 per cent decline in energy consumption compared with what it would have been. Studies based on earlier years did not always find this (e.g., Booth (1966, Part III)). So we cannot exclude the possibility that responsiveness to price might increase. This might in particular be the case if the full response to the 1973/74 price hike, in terms of energy saving technology currently being developed, does not materialise for a while.

The projections to 1990 show a wide range, from about 18 MTOE down to 10 MTOE, depending on the assumption one makes. The high projections assume, however, an average annual GDP growth of 5½ per cent over 13 years, 1977 to 1990, which would be an historic achievement. The more likely assumption for GDP is contained in the first three cases. A plausible range for energy consumption would be from 11 to about 14 MTOE. Some of the uncertainty surrounding the projections may resolve itself after a few more years of data clarify the trends of energy responsiveness to GDP and price.

Chapter 3

A COMPARISON WITH RECENT PROJECTIONS AND FOREIGN EXPERIENCE

In the last chapter we gave the projections of energy demand in 1990 which emerged from our time-series analysis. In this chapter we assess these projections in a broader context. How do they compare with the recent official projections published by the Department of Transport and Power in 1977 and the Department of Industry, Commerce and Energy in 1978 and what does a comparison with international data reveal?

A Comparison with Official Forecasts

A summary of the official forecasts is given in Table 3 below. Both sets of official projections are shown since the underlying relationship between energy and GNP appears to be the same, judging from Figure 3 below. The projections made in 1977 are denoted by 1, and those made in 1978 by 2. The most recent official "best estimate" for energy consumption in 1990 is 18 MTOE[1] compared with 7.51 for 1977, a rise of 140 per cent. This is associated with an official GNP rise of 99.5 per cent, that is a compound annual rise of 5½ per cent, as shown in the fourth column of Table 3 below.

As future energy price levels are not given in the official text, there is no exact match between the official projections and ours. Broadly speaking, the official "best estimate" of 18 MTOE would correspond to our Case IV which incorporates a "moderate" price rise of 20 per cent. Our Case IV ranges from about 17½ down to 13 MTOE, placing the

1. This figure is reduced to 16.5 MTOE in Energy Ireland (Department of Industry Commerce and Energy, 1978a) when conservation is taken into account.

Table 3: *Official forecasts of energy consumption in 1990 with associated GNP assumptions*

	Low 1	2	*Medium* 1	2	*High* 1	2
1977-1990 growth in GNP (%)	47	71	121	100	180	148
Implied Annual GNP growth (%)	3.00	4.23	6.30	5.46	8.25	7.23
Energy consumption 1990 (MTOE)	12.4	15.0	21.4	18.0 ↑ official "best estimate"	29.3	24.0

Note: GNP figures are approximate due to rounding.

official forecast at the top end of our range for this GNP assumption. Similarly, the official projection of 15 MTOE associated with a 71 per cent GNP growth corresponds to our other cases which range from 15½ MTOE down to about 10½ MTOE. Clearly, the official relationship used for any given GNP figure is producing energy levels at the top of our range.

The relationship apart, the underlying assumption in the official "best estimate" is that GNP will grow on average at just under 5½ per cent over the period 1977-1990. To be realistic, this should be re-labelled a "High" assumption. In fact, these official projections are undergoing revision.

The Projections Viewed in the Context of International Experience

We will now view these projections against information from other countries. Foreign experience provides a useful check so long as one takes care to recognise the different influences on energy use resulting from different conditions between countries.

Figure 3 overleaf plots the total energy consumption per head against GNP per head for 22 OECD countries in 1976. There is considerable variation about the trend line for which one would seek explanations in the differences in energy pricing policies, in the composition and scale of output, in the type of technology, in population density, in climate, and so on. Superimposed on this graph are the official projections for 1990 and the results of our time-series analysis. The official projections are well above the plots for other countries. Our time-series projections are, if anything, also on the high side of the international trend.

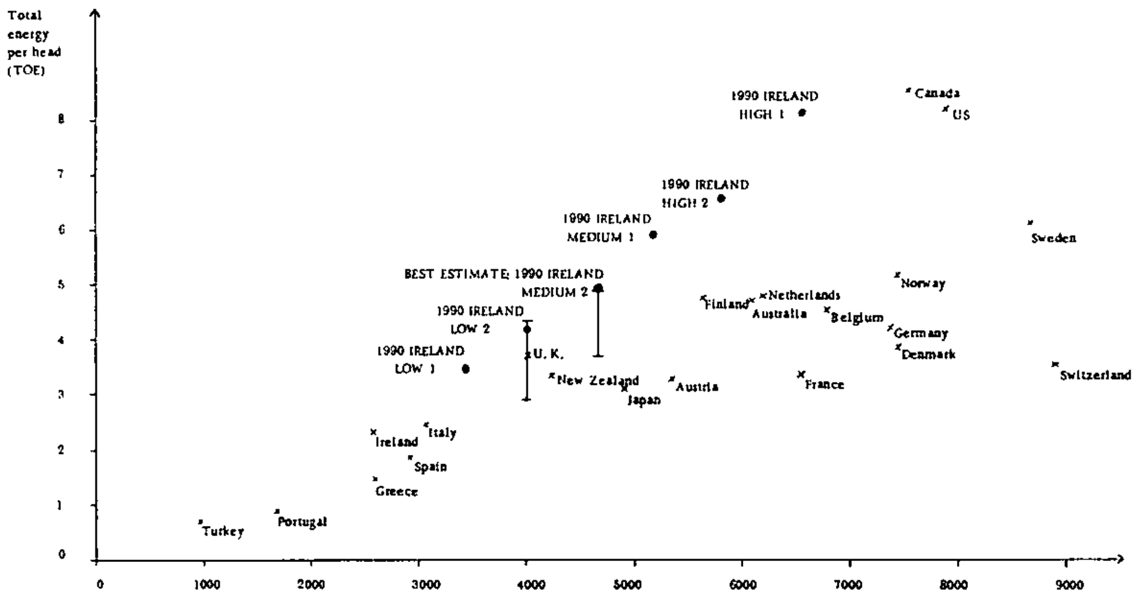
Before we investigate whether the international trend itself is moving upwards or downwards, we should try to tackle an important problem which arises in international comparisons of this sort. The problem centres on the GDP (or GNP) *per capita* expressed in a common currency such as the United States dollar. We use GNP *per capita* because we want a measure of wealth or purchasing power, but exchange rate conversions to a common currency do not yield a reliable comparison of purchasing power. In particular, Kravis *et al* (1978a), describe how the real *per capita* GDP of low income countries relative to that of high income countries is greater than is indicated by comparisons based on exchange rate conversions of GDPs to a common currency.

Kravis has adjusted the figures of nominal GDP per head for 16 countries to give real GDP per head. Ireland is not among the sixteen. However, Kravis has estimated real GDP per head for Ireland, among other countries, by extrapolating the relationship between real GDP per head in the sixteen and certain independent variables including measures of exposure to world markets and of price isolation. Kravis notes that the estimated figures of real GDP *per capita* are subject to large margins of error, but are almost surely substantially closer to the true figures than the "nominal" measures commonly used.

It is interesting to redraw Figure 3 plotting energy consumption per head against Kravis' figures of real GDP per head. This is given[2] in Figure 4 which shows a noticeably stronger relationship between energy consumption and real GDP per head than given in Figure 3. The correlation coefficient has improved from .79 in the previous graph to .90

2. Kravis' most recent figures are for 1974. These were roughly updated to 1976 using 1974-76 growth rates from OECD Economic Outlook Nos. 21 and 23, July 1977 and 1978, and 1974-76 population changes from UN Demographic Yearbook 1976, Table 5.

Figure 3: Total energy consumption per head against GNP per head for OECD countries in 1976, with the official projections and our time-series projections for 1990 superimposed

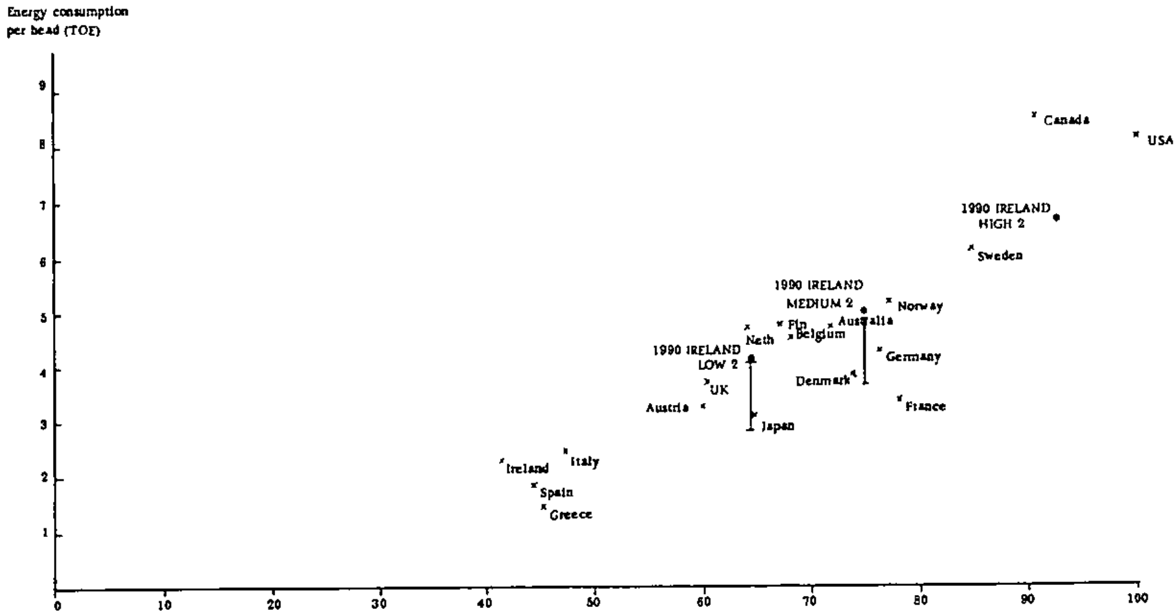


Official Forecasts denoted by : ●

Forecasts from Chapter 2 (Table 2) denoted by : I

Source: Energy per head from OECD Observer March 1978. GNP per head from World Development Report, 1978. (World Bank)

Figure 4: Total energy consumption per head against REAL GDP per head for OECD countries in 1976, with the official and our time-series projections for 1990 superimposed



SOURCES: Energy /hd from OECD Observer, March 1978
Real GDP/hd from Kravis et al., Economic Journal, June 1978

Official forecasts denoted by • .
Forecasts from Chapter 2 (Table 2) denoted by I

implying that real GDP gives a better explanation of energy consumption than nominal GDP. It is also interesting to see how the ranking of energy intensiveness of GDP (as measured by the slope of the line joining the origin to each country's plot) has changed. Instead of being fourth in energy-intensiveness, that is only less energy intensive than Canada, US and UK as seen from the previous graph, Ireland now moves to the middle, to the level of Germany. This is a considerable improvement, though to be on a level with Germany in energy intensity seems high still. However, there are aspects of each country which might influence energy intensiveness in different ways. On the one hand, Germany has a higher proportion of heavy industry and a colder climate, on the other hand, its population density is between five and six times that of Ireland, its climate is less damp and it has more opportunities to benefit from economies of scale. It is also possible that Germany, like some other advanced economies, has a higher proportion of service-type industries and industries with a high skilled labour content. However, regardless of which GDP measure is used, it is evident that Ireland ranks among the energy-intensive nations of the world.

When the projections are superimposed on this graph a different picture emerges. The time-series projections are more central for each given GDP level. The official projections, though more reasonable now that they are plotted against real GDP are still not far from the upper edge of the plots. For GDP per head lying between 60 and 70 (US = 100), Ireland is superseded by Netherlands, Finland and Belgium, which three countries respectively have a high proportion of indigenous energy, a harsh climate and a high level of steel production relative to most of the countries. For GDP per head lying between 70 and 80, (US = 100), Ireland is only superseded by Norway, where practically all electricity is generated by hydro.

Our discussion must now turn to ask whether the entire international scatter of plots shows signs of shifting upwards or downwards over time. To be specific, we want to know what, if any, have been the changes in energy intensiveness of GDP in these countries. If a country is moving such that the slope of the line from the origin to the new position is less than to the old position, then the energy intensiveness of GDP is declining. Table 4 below shows the growth rates of GDP and energy consumption for the period 1963-73, during which energy prices declined, and for the period 1970-76 which saw a price rise. The last two columns give the ratios of the growth rate of energy to the growth rate of GDP for each country. A ratio of less than 1 indicates that the energy intensiveness of GDP was declining and a ratio greater than 1 indicates that the energy intensiveness of GDP was rising. A negative means an absolute decline in energy consumption over the period.

The last two columns suggest two features. The more advanced countries tend to have lower ratios, unless they have large indigenous supplies of energy, such as the Netherlands or Canada. This suggests that the more advanced countries have a different composition of output and/or they are

Table 4: *Average annual growth rates of GDP and energy consumption*

	Average annual growth rates				*Ratio of growth rates of energy to GDP*	
	1963–73		*1970–76*			
	GDP (1)	*Energy Cons. (2)*	*GDP (3)*	*Energy Cons. (4)*	*1963-1973 (5)*	*1970-1976 (6)*
Eur 9	4.5	4.50	2.97	1.98	1.0	.66
Eur 6	5.0	5.39			1.07	
Germany	4.6	4.31	2.52	1.65	0.94	.65
France	5.5	5.37	4.10	2.86	0.98	.70
Italy	4.7	7.29	2.97	2.56	1.55	.86
Netherlands	5.5	8.11	3.62	4.80	1.47	1.33
Belgium	4.9	4.28	3.94	1.25	0.87	.32
Luxembourg	4.0	3.21	1.95	−0.02	0.80	−.01
UK	2.9	2.09	2.00	−0.005	0.72	−.003
Ireland	4.4	5.62	3.10	3.43[a]	1.28	1.11[a]
Denmark	4.8	5.08	2.49	−0.005	1.06	−.0002
USA	4.2	4.48	2.87	1.76	1.07	.61
Canada	5.5	6.32	4.99	4.04	1.15	.81

Sources: Col. 1 Basic Statistics of the Community 1973–74, Table 13: Annual Rates of Growth of GDP (at constant market prices).
Col. 2 & 4 OECD Energy Balances 1974/76, p. 26.
Col. 3 Basic Statistics of the Community 1978, Table 16.
a Figures based on Energy-Ireland, 1978, p. 17.

able to replace existing capital equipment with more efficient equipment, so their energy intensity falls, or rises less rapidly. The present high ratio for Ireland may reflect its developing status (see page 49). Secondly, the period of the large price rise 1970-1976 has consistently lower ratios than the first period, supporting the view that energy intensity is responsive to price. So the indications are that energy intensiveness abroad is unlikely to rise and may well fall, at least if there is a period of sustained energy price rises. Indeed this has been made a target of policy. For instance the European Council (Bremen, July 1978) adopted the objective of a ratio of 0.8, for what it is worth. Should this occur, in terms of our graphs, the top ends of the projections will be higher still relative to the other countries, leading one to question whether the fulfilment of these projections is likely.

Other Forecasting Approaches Required

So far in this paper discussion has centred on national totals of energy consumption and their forecasting. Fortunately there are several approaches to forecasting. In particular it may be more worthwhile to build up forecasts for the individual consuming sectors. There is a breakdown by consuming sector in the official projections, but it is not clear how these were derived. In particular the official forecast of 1990 energy consumption by industry implies a 40 per cent growth in the energy intensiveness of industrial output. Obviously, while Ireland's industrial sector is growing the actual quantity of energy is likely to rise, but only if more energy intensive processes or products are being introduced will energy *per unit of output* rise. Our information on this is poor. Information on past trends currently available for four European countries, namely, the UK, France, Germany and Holland are given in Table 5 below. This gives the trend of energy intensity by sector over the period 1960-1974 during most of which time energy prices were in fact falling.

The preponderance of declining intensities suggests that once a sector has "industrialised" its subsequent capital replacement is more energy efficient. What are the trends in the configuration of labour, capital and energy in Irish production likely to be? Are machines being introduced for the first time, or are there already machines being used which will in time be replaced by more energy efficient machines? These questions need to be investigated for each sector.

Table 5: *The trend of energy intensity over the period 1960–1974 in four European countries, by sector*

Sector	*UK*	*France*	*Germany*	*Holland*
Iron and steel	–	–	–	–
Aluminium	–	–	– +	+
Other non-ferrous metals	–	–	–	
Glass	–	–	–	
Cement	–	–	–	+
Other building materials	–	+	–	
Chemicals	–	+	–	+
Paper and pulp	–	–	–	–
Other industries	–	–	–	–
Land transport	0	–	–	0
Sea and air transport	0	+	– +	+
Other services	0	+	+	+
Private transport	–		+	–
Other household uses	0		+ –	+

Sources: Report on EDM in the EEC energy modelling programme. UK information is derived from the coefficient in double log equations.

– = declining energy intensity   0 = constant energy intensity
\+ =rising energy intensity   + – = decline followed by rise and vv. for – +

We notice from Table 5 that Holland is an exception with a predominance of rising intensities. This may be related to the abundance of natural gas which became available and which may have affected the composition of output within the classifications used here. The composition of output is another factor of major importance when considering future energy demand and we need to have some idea of the types of new firms which are likely to establish here. Whatever they are, we ought to be able to assume that they will adopt the new more energy efficient machines and processes now becoming available.

An industry by industry consultation and analysis is needed if only to ascertain the direction of energy intensity.

Between 1962 and 1973 we have some evidence that it was growing in most industries. But we also know that Ireland now ranks quite high in energy intensiveness of GDP by world standards. Until we have more knowledge of what is happening in industry, we are hampered in our efforts to estimate future energy consumption.

Chapter 4

SUMMARY AND IMPLICATIONS FOR POLICY[3]

The results of our analysis can be summarised as follows:

1. Energy demand in 1990 will be considerably higher than today's level of around 8 MTOE, but it may be lower than the official forecasts published in 1978. Given that we are uncertain about the course of the main factors which determine energy demand, namely GDP, the real price of energy and technology trends, the range of likely outcomes, from 11 to 14 or 15 MTOE, is quite large.
2. While demand for energy is not very responsive to price in the short term, in the long term demand seems to be much more responsive to price. Using past evidence as a basis, a 10 per cent rise in the real price of energy (that is the Fuel and Light price index deflated by the All Items price index) brings about a decline of approximately 7 per cent in energy consumed after a time lag of several years.

It remains now to assess the implications of these results for energy policy. Before this can be done, however, we need to clarify the reasons for having an energy policy and to examine the role of government, its aims and the means for implementing energy policy. This done, we will consider the record so far, particularly in the light of our second result above, which relates to price. We conclude with a set of principles which could provide the framework for a coherent energy policy.

Why do we Need an Energy Policy?

Since we are content to leave the levels and pattern of consumption of many commodities to be allocated by the market, it is worthwhile asking why we need a national energy policy at all. Why is energy so special?

3. Much of the material in this Chapter was drawn from McCarthy (1979).

The usual answer to this question is that energy is so essential and so pervasive. It is used for heating, transport, motive power, and lighting, and it is used by all sectors of the economy. Our lifestyle in the recent past has become adapted to relatively cheap energy such that minor disruptions in supply cause serious economic and social disturbances. However, this factor on its own would mainly call for an energy stock-piling policy to enable us to ride out temporary disruptions. Longer disruptions might be mitigated by having diversity of fuels and suppliers as well as by having unused indigenous resources.

The second factor which makes energy different is its very large import content. Three-quarters of our consumption is imported oil. The bill for these oil imports amounted to £330m in 1978, or 9 per cent of total imports and 6.3 per cent of national income. However, this is not a strong reason for singling out energy for special treatment while not doing so with the other 91 per cent of imports.

A third factor is our membership of the EEC and the IEA. These bodies have energy policies, both laying strong emphasis on conservation. There is an obligation on us to abide by the rules of these organisations. However, since most member states of these organisations consume more, and some a good deal more, energy per head than the average Irishman, they only have a strong position in arguing that Ireland should consume less energy per unit of GDP. As we saw Ireland appears high on this score though this may partly be an illusion due to measurement conventions. Nevertheless, Ireland might face sanctions, if energy effectiveness fell to any large extent.

A fourth factor is that fossil fuels, which constitute 97 per cent of our present energy consumption, are a depleting resource. Therefore, it is argued, all nations should combine to consume less energy than they would do, at the going price, to make it last longer. This is often viewed as a moral argument; indeed one can derive moral satisfaction from energy conservation *per se.* Appropriate resource conservation can be described as an investment for the future in the usual sense that present consumption is given up for the sake of future benefits. However, except in the case of our own native resources where this might apply, restraining consumption of *foreign* resources is hardly going to cause more resources to be left over for Ireland at the end unless all energy importing countries restrain consumption together. We account for a mere 0.14 per cent of global energy use. Indeed even if most importing countries manage to combine to restrain consumption, but one large bloc fails to do so, the result is likely to be that the "selfish" bloc will reap the benefits of the lower price (relative to what it would have been) and raise its consumption into the bargain. The argument so far for restraint on the part of a small country is not strong, though the argument for urging joint action on the part of all energy importers is stronger. We will need to look further for the *raison d'etre* for an energy policy in Ireland.

We said that fossil fuels are a depleting resource. This means that as depletion occurs their prices will rise up to those of the renewable energy resources, biomass, wind etc. We do not know what this new price will be. In the US, Manne (1979) has given the present price of these so-called backstop technologies at between two and three times the current OPEC price. In the case of Ireland at present some may be lower[4] and some higher. It is uncertain when this new price will prevail since new reserves may be found in the meantime, the rate of depletion will vary and new coal technologies are likely to intervene. The eventual price of renewable resources is also uncertain since technological improvements may reduce the currently expected future price. There is also uncertainty about how smooth this transitional price rise will be. One study, by Gately and Kyle (1977) looks at various price paths as seen from OPEC's point of view. Their conclusions are that OPEC's interests may be well served by a strategy that is "relatively cautious about further major, abrupt price increases. Such a strategy, closely resembling the position reportedly advocated by Saudi Arabia, would

4. If there exist unemployed factors of production, then appraisals of these new technologies, using conventional accounting criteria, are likely to overstate the costs in national terms. For example, the cost in national terms of employing labour that would otherwise be unemployed is lower than the market wage.

increase price only gradually when market conditions warrant and would cut price aggressively if necessary to defend OPEC's market position."

However, they add "more aggressive pricing strategies may also yield as good or better results for OPEC. Hence, consuming countries should not ignore the possibility of further abrupt price increases, perhaps a doubling or tripling of price within the next ten years." The sudden demand for renewable energy resources resulting from such abrupt price increases would meet bottle-necks and cause the price to overshoot the longer term price temporarily.

In sum, then, we can say that the price of energy will eventually be the price of renewable resources but we do not know what the transition path of price will be. Present indications are, however, that the price of renewable resources is higher than current fossil fuel prices, so the present view must be that we have to adapt to higher energy prices, in any case. The main thrust of energy policy must be to enable this to happen in a sensible manner.

The Role of Government

We must ask to what extent the government, as opposed to market forces, has a role to play in energy matters. Views differ on this issue. On the one hand, there is the view that governments show no evidence of being far-sighted or of understanding individual circumstances, and that anyway, due to electoral pressures, they are "four-year optimisers". On the other hand, there is the view that individuals are myopic, they cannot take long-term decisions and cannot be as well informed as governments. Doubtless this debate will continue but there are some further aspects to take into consideration where energy is concerned.

The government is already involved directly or indirectly with matters affecting energy. It is engaged in taxing energy, in controlling energy prices and in controlling semi-state bodies which use or produce energy and require funding or approval from the government. Therefore it is inevitable that the government be involved in energy policy to a large extent. There are a number of restrictions, licences, laws and so on, which affect energy demand or the response of demand to price. Obviously these have to be tackled at government level where many originated in the first place. In addition, given the high levels of uncertainty about the future, only with government support will some of the more costly long-term research projects into renewable resources be undertaken. The risks of delayed returns are large, and governments are better able to take these risks than private concerns. Furthermore, referring back to the analysis of previous chapters, we saw that consumers respond to price but after a lag. In other words the price mechanism, while operating, does so in a sluggish manner at present. Government can provide encouragement to speed up responses.

The Aim of Energy Policy – Adaptation

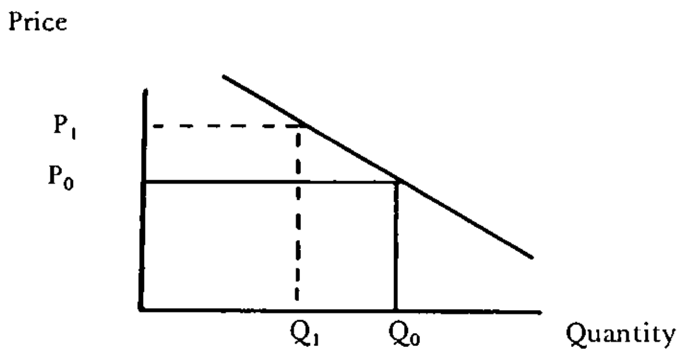
It cannot be denied then that the government has an important role to play. It is also clear that the ultimate aims of its energy policy must be to proceed with a wide ranging process of adaptation to consuming lower levels of fossil fuels as their world prices rise. This should be accompanied by a progressive introduction of renewable resources. Included with these are the fossil fuels with long-term promise, e.g., coal. It is adaptation rather than mere conservation that is needed. Adaptation includes conservation and should entail long-term substainable effects rather than just temporary sacrifices of comfort. In other words, gradual structural changes are required. These changes will be more difficult to bring about than the painless adaptation to falling real energy prices of the previous decade.

In the next section we look at the possible strategies which may be used in pursuit of such a policy.

Possible Strategies: Rationing, Exhortation, Directives and Pricing

The alternative methods of altering the pattern of demand for any group of goods are (a) rationing, (b) exhortation, (c) directives and (d) pricing including (i) taxation and (ii) decontrol. We will illustrate each of these options with the aid of a demand function which describes the quantity of a good demanded at various prices. Our examples show how consumption can be reduced, though they could equally be used to illustrate how consumption can be raised. (For ease of exposition we assume infinitely elastic supply).

(a) Rationing. By this we mean formal rationing. Initially we have price P_0 with corresponding quantity demanded Q_0.

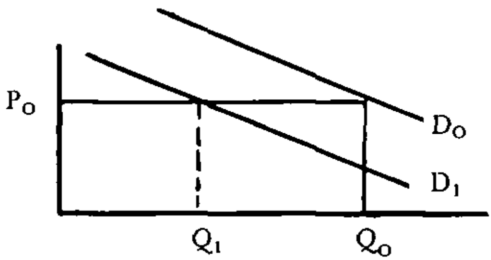


The officially desired volume of consumption is Q_1. Rationing can achieve this and the incipient rise in price to P_1 is prevented. Unsatisfied demand at this price is $Q_0 - Q_1$ and a "black" market might or might not emerge depending on the effectiveness of policing. The fact that rationing does not remove the excess demand is one disadvantage. Its rigidity is another, in that interpersonal differences can only be catered for to a limited extent. Nevertheless, rationing is often advocated on the grounds that it is "fair" or less arbitrary than rationing by queueing, such as we have had for short periods in recent years.

A well known variant of rationing suggested by Walsh (1979) applicable to petrol rationing, for example, would entail issuing all persons the same coupons, regardless of whether they were pedestrians or what sort of car they drove. These could be used for buying petrol at price P_0 or they could be sold at whatever is the going market price for coupons ($P_1 - P_0$ in this case.) This system ensures that everyone can get a minimum quantity of fuel at the low price P_0. Beyond this quantity they have to buy coupons from someone who does not want his, paying in all the market price P_1. This system removes excess demand and redistributes income to those who use least petrol or none. The average price paid is less than P_1, but greater than the artificial low P_0 imposed under a conventional rationing system.

Rationing has an important role when there are disruptions which are temporary, though not too temporary in view of the administrative costs involved. Rationing may be preferable in a crisis to a market clearing price because people will not have had time to adjust. For the longer term, the case for or against rationing should rest on whether it is the best method for bringing about the widespread adaptation of which we have spoken.

(b) Under *exhortation*, the authorities use advertising or similar means in an attempt to shift the demand curve inwards from D_O to D_1. The market now clears at the old price with no excess demand and no need for quantitative interventions.



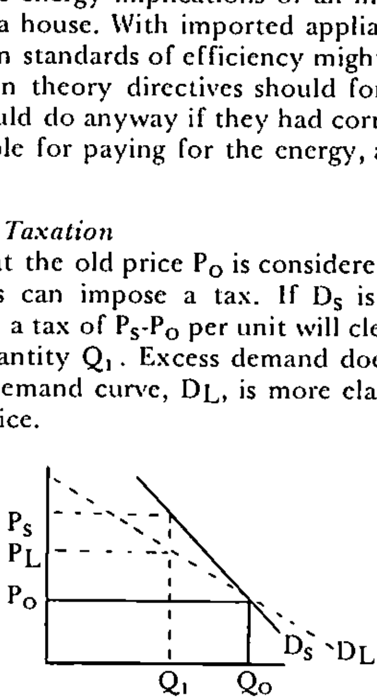
The political expediency of this method may account for the noticeable increase in official publicity campaigns in one sphere or another. Given that energy conservation is a long-term problem, it must be asked whether campaigns of exhortation would have to be permanent in order to be effective. The public might lapse from whatever level of virtue they had attained as soon as the campaign ceased. These campaigns can be costly. Even with permanency their cost effectiveness is questionable. Also, problems arise which are similar to those encountered in the international context when some members do not restrain consumption.

However, exhortation can play a useful role if it is combined with a supply of information. The public will not conserve energy, even though it would pay them, if they do not know how to go about it. Details of good housekeeping practices, good driving practices and so on are all useful. More information on potential money savings from conservation, more technical assistance and more consumers' association-type analyses of methods and brands would also be desirable. These might help cut down the long time spent by consumers searching out information, which, if they have not lost interest, at least delays their actions.

(c) *Directives.* Similar to exhortation is the method of directives, such as the setting of insulation standards in buildings. These also attempt to shift the energy demand curve leftwards. Directives have varied possibilities and are worth looking at for cases where the consumers of energy are not directly responsible for paying the bill, for example, for the temperature level in offices. They are also essential when the consumer cannot be expected to have the expertise to judge for himself the energy implications of an investment like an appliance, or a house. With imported appliances, only those meeting certain standards of efficiency might be allowed into the country. In theory directives should force people to do what they would do anyway if they had correct information, were responsible for paying for the energy, and acted rationally.

(d) *Pricing: (i) Taxation*

If demand at the old price P_O is considered to be too high, the authorities can impose a tax. If D_S is the (short run) demand curve, a tax of P_S-P_O per unit will clear the market at the desired quantity Q_1. Excess demand does not appear. If the long-run demand curve, D_L, is more elastic, a lower tax P_L-P_O will suffice.



The objections to regulating demand by price, rather than by rationing, rest on a concern that low income people will be hard hit, that industrial production costs will be raised and that the rise in the CPI will generate inflationary wage demands. This argument usually rests on the assumption that the alternatives to using price as a regulator are costless which is clearly not the case. It also rests on the assumption that when a tax is imposed the extra government revenue somehow disappears, or is spent in the wrong area. However, if a tax were imposed on energy, there is nothing to stop the proceeds of the tax being used to reduce the tax on other consumer items which feature in the CPI. Similarly, in the case of the manufacturer, the proceeds from a tax on energy can be used to reduce tax or raise subsidies on some other factor of production, such as labour. Government policies of the past two decades have lowered the cost of capital relative to the cost of labour. (Geary, and MacDonnell, 1979). This encouragement to capital intensive production may incidentally have been a stimulus to energy intensive production.[5] Some attempts to mitigate this could now be made by using extra energy revenues to reduce the costs to the manufacturer of employing labour. At least such intervention will be working more in the desired direction, where labour, capital and energy are concerned, than at present; so regulating energy demand by price does not simply mean raising tax, it could mean switching taxes. This is in marked contrast to a price rise imposed by OPEC, for which obviously we cannot compensate ourselves.

Of course all the arguments in favour of using price to control demand rest on the assumption that demand is not totally inelastic with respect to price. That is to say, if price is raised quantity demanded will fall. This assumption is justified by the results of our analysis. It is true that short-run response is small particularly for fuels which have no near substitutes, such as for petrol when public transport is inadequate. Response will be small when technology changes are expensive, such as the introduction of some conservation measures.

5. See Appendix 7 for elasticities of substitution for energy and capital calculated for the US.

Response might also be small when the consumer lacks the expertise to judge the energy implication of his actions, as mentioned above, or when he does not have to pay for them directly anyway. As already stated, directives and information might be appropriate here. In general, in cases where response to price changes is small it is worth first investigating why this is the case. It may be easier to remove the cause and then use pricing, than to resort solely to one of the other strategies. Examples might be the introduction of individual meters for each flat in apartment blocks or the introduction of bicycle paths. In any case there is no evidence that demand for energy is totally unresponsive to price, especially in the long run, which concerns us here.

Pricing: (ii) decontrol

It is widely observed at present, that price control of energy operates to keep prices down. There is no evidence to suggest that energy supply is unresponsive to price changes, other than in the short term. Therefore, in addition to influencing demand, a rise in the price of fossil fuels will increase profitability of other sources of energy at the margin, that is of indigenous fossil fuels and renewable resources. In the case of the national research effort investigating new fuel technologies and renewable resources, a rise in the price of fossil fuels will increase the expected return from any given expenditure. At present, a major obstacle in the way of widespread experimentation and demonstration is the low monetary value of the fossil fuels saved and the expectation that the real price of energy may not be allowed to rise.

Opposition to decontrolling the price of indigenous fossil fuels often stems from a view that the suppliers will make large profits. This might not be undesirable since large funds are required for research into and developments of long-term energy supplies.

Apart from its effects on supply, the pricing of indigenous resources to the consumer at levels below the world energy price will lead to a misallocation of those resources. Exceptions might be made in the short term to build up a market, provided this can be made up in the long term. Underpricing amounts to a subsidy, a subsidy encourages additional consumption, which is the opposite of what is required.

So much for the theory. We have a classic example of what happens in practice when price is ignored. Project Independence in the US attempted to deal with the threat of future oil embargoes by cutting back imports but with price controls maintaining an artificially low price. The result, according to Jorgensen (1978) was "that demand was allowed to rise more rapidly than it would have risen . . . domestic supply to fall more rapidly than it would have fallen. The impact of Project Independence was a dramatic increase in petroleum imports". If Ireland is really interested in tackling the task of adaptation and conservation, we must learn from experiences of this type and realise that pricing will have an important role to play along with some of the other strategies.

We will now turn to evaluate the record on energy policy so far.

The Record

(a) Formal rationing has not been implemented in recent years, probably rightly given the circumstances.

(b) Exhortation is widely applied. Much of it contains useful information[6] to enable the consumer to use energy wisely. People will tend to follow the advice up to the point where the perceived net gain falls to zero. Unless the perceptions are changed, further expenditure on exhortation is a waste of public funds. There is clearly a growing interest in energy conservation. It is difficult to know how much is attributable to the exhortation and how much to a gradual common sense reaction to the 1973/74 and 1979 price hikes.

(c) Some directives have been issued for example in the form of requirements of thermal insulation levels in public sector house construction. This was extended belatedly to private sector housing in 1978/79 as qualification for a Certificate of Reasonable Value. Some would view the standards for walls as inadequate, and the application affects new houses only. Even, here, application is not universal. Clearly a high level of commitment is required for the application and monitoring of directives. In addition, a coherent programme for adaptation will require a programme of directives introduced over a span of years.

6. See, for example, IIRS publications.

Some existing directives in other spheres are counter-conservationist, such as prohibition on own account road hauliers from carrying back loads after making their own deliveries. Some means of bestowing the benefits of such rules might be sought, which are less wasteful of energy.

(d) The record on pricing is poor. The criticism is not simply that price has been ignored through not switching taxes from other items to energy. The criticism is also that pricing has been used in the opposite direction to that which is required. It has acted as an encouragement to increased consumption, as we now show.

For a given group of commodities, their relative prices will affect the relative quantities bought. Compared with a uniform tax, a lower tax rate on one particular commodity encourages its consumption rather than merely fails to discourage it. We might ask, then, what is the rate of tax on energy compared with that on other goods. We find that the average rate of indirect taxation less subsidies on personal expenditure on all goods and services is 15 per cent (NIE 1977). However, apart from the transport fuels, energy has practically no tax imposed on it. Coal, turf, electricity and towngas are chargeable at the zero rate of VAT. Non-transport oils pay excise duty at a rate of about 4 per cent. In other words, three-quarters of all energy in Ireland is sold almost tax free. This favoured tax position for energy, relative to so many other products and services consumed, is not generally recognised.

The transport fuels, petrol and diesel and a small amount of LPG, which account for about 23 per cent of all primary energy consumption, face excise tax and VAT and yield a sizeable revenue. It is quite reasonable to regard the taxes on these oil products, combined with the annual licence fees, as payment for road track costs, although these costs are not related in any simple way to an individual vehicle's fuel consumption. The National Prices Commission (1973) attempted to show the extent to which various categories of road user paid their way in 1970/71. While all categories were found to be contributing more than the costs they imposed, the estimates took no account of external costs such as congestion, accidents, loss of amenity and pollution. Since then the annual licence fees have been greatly reduced in real terms, or abolished. Also, since then, the total taxes imposed per gallon of road fuel have declined in real terms. Indeed the tax per gallon of road diesel has more than halved in real terms. Therefore it has to be shown whether road users, especially users of road diesel, are now covering the costs they impose. If they are effectively being subsidised, this would have long-run effects via the location of factories, warehouses and so on.

When a subsidy is considered essential for the viability of an enterprise which is worthy of being maintained, the subsidy should not be granted through tax reduction on their energy inputs. This is currently the case with towngas enterprises and passenger road transport. These subsidies could be given directly so as not to cheapen energy inputs.

The time-path of energy price is a separate issue. We saw in the first chapter that between 1974 and 1978 there was a fall in the Fuel and Light price index relative to consumer prices in general. This was possibly undesirable in the context of the long term. Inertia on the consumer's part tends to be rewarded, until the next big rise, which is more disruptive than it need be. Theoretically it is possible for governments to have an energy price stabilisation policy. While it might be difficult to determine what the "correct" price rise should be, it should be possible to prevent real price from falling. This might complement macro-economic stabilisation policy. In practice there could be difficulties but it is worth investigation.

The record on pricing of indigenous energy resources is questionable. It would appear that neither turf nor natural gas is priced close to the world price of the fuel for which it can substitute. In the case of turf this would be roughly the price of coal, on a therm for therm basis. For natural gas this might be roughly the price of gas oil. The reasoning is that a therm of natural gas can save us from importing a therm of gas oil, which in turn saves us from having to export goods to that value in order to pay for the gas oil. This is the value to the nation of the natural gas as was explicitly recognised by the Minister in his statement on the Kinsale Head gas (reproduced as Appendix 9).

> Natural gas should in general be allocated . . . on the basis of market prices. . . . The pricing arrangements with the ESB in relation to its allocation of natural gas should be

reviewed as soon as possible with a view to determining what would be an appropriate energy related price.

Charging less than a price related to the world price of the fuel it can substitute for amounts to a subsidy. If it is considered necessary to subsidise the purchasers of natural gas, the subsidy is better given explicitly rather than through cheapening the gas as this reduces the incentive to use this input efficiently relative to other inputs. If processors of natural gas and turf receive it at, in our sense, a subsidised price, which is then passed on to the consumer, we have the anomaly that consumers of large amounts of such products receive more subsidies than consumers of small amounts. High income households spending more, in absolute terms, on such products would therefore receive most subsidy. Granted that poor households may spend a higher proportion of their disposable income in this way, than do richer households, the subsidy might help the poor proportionately more. However, it is widely recognised (Fletcher 1972, Webb 1978) that tackling poverty through the manipulation of energy prices is a blunt instrument which leaves the underlying causes of poverty untouched. In the current circumstances it is also highly undesirable. It would encourage a higher consumption of energy than would otherwise have occurred and give misleading signals to the planners determining future processing capacity.

On a more positive note, there has been official action to reduce the price of conservation measures to energy users, through grants of various kinds. These include grants for fuel efficiency in industry, grants towards approved expenditure on equipment which will reduce energy usage, grants towards R & D projects which have a significant technical input aimed at conserving energy, and subsidies for boiler efficiency tests. Home improvements grant are available for conservation measures undertaking in houses.* It is difficult to estimate from published sources the total amount of money made available. Of course more money could be available for con-

* Since this report was written, the home improvements grant scheme has been discontinued.

servation, and applied for, if an extra tax were imposed on energy.

Many low income households would be unable to avail of the grants. Some programme like the "Weatherisation" programme in the USA where an employment scheme is used for house-insulation in low income households, might be appropriate.

We have not in fact evaluated the relative costs and benefits of the existing conservation measures. While they seem to be aimed in the right direction, energy conservation measures should properly be evaluated in the context of the task of *transition ahead and using accepted project appraisal methods* (Ruane 1979). These take account not only of the energy saving, but the costs of achieving the energy saving, in terms of other resources, properly valued.

This is a mixed record so far. Government support for conservation through exhortation and grants has to some extent been cancelled out by the remainder of its pricing policy which has reduced energy conservation. Energy pricing has not even been neutral. The past five years have seen a succes*sion of tax reductions on energy and energy using* appliances, combined with price controls and subsidies. The minimum, neutral, role for government is to remove those aspects of pricing which are counter-conservation. Then, if it is considered that the government should play a positive role in the long term widespread adaptation to more expensive energy in the future, an active pricing policy will be needed, along with some of the other strategies.

Principles

In the light of the foregoing analysis the following would seem to be sensible principles to apply. They are by no means exhaustive.

(a) Remove the virtual exemption of most energy from tax by imposing VAT on all fuels.
(b) Mitigate the regressive distributional effects by using some of the proceeds for a programme to compensate low income households.

(c) Use the remainder of the proceeds to reduce taxes or raise subsidies on other items. The emphasis might be on subsidising goods, activities and investments, at domestic and industrial level which promote the desired long-term adaptation.

(d) Indigenous fuels should be priced near the world price of their equivalent fuel, on an equivalent energy basis. This includes any potential discoveries of hydrocarbons. From the energy user's point of view, the energy intensive alternative must not artificially be made to be the cheap alternative.

(e) For the same reason as given in the last sentence, where subsidies are considered desirable, the subsidy should be explicit or granted on non-energy items and not granted through price or tax reductions on energy.

(f) Introduce firmer directives progressively and with due warning for building insulation standards and for energy use in buildings. Other rules and practices, remnants of the cheap energy era, which work in the opposite direction to energy conservation should be removed. Current protections offered by such practices, if desirable, could be granted by some other route.

(g) Continue the information campaign with less emphasis on exhortation, more on helping the consumer and consumer associations to make their own calculations. Consumers' own analyses carry more validity for them and they will be better equipped to re-evaluate proposals when prices alter.

(h) Investigate the feasibility of an energy price stabilisation policy which aims at removing misleading temporary declines in real price.

This list only covers the more immediate points raised by the results of the previous analysis. A strong emphasis on price has been made in this chapter. The reasons for this are threefold:

(i) our previous analysis showed that price does have an effect on demand,

(ii) because this is not sufficiently recognised and because decisions have been taken without adequate concern for energy pricing, recent pricing policy has, if anything, operated in the wrong direction and

(iii) the current view of the renewable energy sources is that they cost more. Our long-term task of widespread adaptation to these new sources can hardly be achieved without a coherent pricing policy.

REFERENCES

ARTHUR, W. B., 1973. "The Elasticity of Demand for Petrol in Ireland, a comment", *The Economic and Social Review*, Vol. 5, No. 1, pp. 105-107.

BOOTH, J. L., 1966/67. *Fuel and Power in Ireland: Part I, Energy Consumption in 1970*, Paper No. 30. *Part II, Electricity and Turf*, Paper No. 34. *Part III, International and Temporal Aspects of Energy Consumption*, Paper No. 35. *Part IV, Sources and Uses of Energy, Paper No. 37*. Dublin: The Economic and Social Research Institute.

BROOKES, L. G., 1972. "More on the Output Elasticity of Energy Consumption", *Journal of Industrial Economics*, Vol. 21.

DARMSTADTER, J., 1971. *Energy in the World Economy, A statistical review of trends in output, trade and consumption since 1925*. Baltimore: Johns Hopkins Press.

DEPARTMENT OF INDUSTRY, COMMERCE AND ENERGY, 1978. *Energy Forecasts, 1978-1990*.

DEPARTMENT OF INDUSTRY, COMMERCE AND ENERGY, 1978a. *Energy Ireland* Discussion Document on some Current Energy Problems and Options.

DEPARTMENT OF TRANSPORT AND POWER, 1977. *Energy Forecasts 1977-1990*.

DHRYMES, P. J., 1971. *Distributed Lags*, Edinburgh: Oliver and Boyd.

EAS, 1975. *Econometric Analysis System*, User Manual, (R. E. Just and S. M. Fletcher, Oklahoma State University).

FEENEY, B. P., 1976. *The Demand for Fuel*, RT. 162, Dublin: An Foras Forbartha.

FEENEY, B. P., 1979. "Energy in Road Transportation," Dublin: An Foras Forbartha, Seminar 31 October.

FLETCHER REPORT, 1972. *Report by the ESB Investigation Committee*, Dublin: Stationery Office.

GATELY, D., and J. F. KYLE, 1977. "Strategies for OPEC's Pricing Decisions", *European Economic Review*, Vol. 10, No. 2, November.

GEARY, P. T., 1973. "The Demand for Tobacco and Petrol in Ireland", *The Economic and Social Review*, Vol. 4, No. 2.

GEARY, P. T., and E. McDONNELL, 1979. "The Cost of Capital to Irish Industry: Revised Estimates", *The Economic and Social Review*, Vol. 10, No. 4.

GUJARATI, D., 1978. *Basic Econometrics*, McGraw-Hill.

HUDSON, E. A., and D. W. JORGENSEN, 1978. *Economic Impact of Policies to reduce US Energy Growth*, Mass.: Harvard Discussion Paper, No. 644.

JORGENSEN, D. W., 1978. *The Role of Energy in the U.S. Economy*, Mass.: Harvard Discussion Paper, No. 622.

KEATING, W., 1976/77. "An Analysis of Recent Demographic Trends with Population Projections for the Years 1981 and 1986," *Journal of Statistical and Social Inquiry Society of Ireland*, Vol. XXIII, Part 4.

IIRS., 1979. *Energy Management for the Householder*, Free Booklet — also six Reports — (1) *Energy Management in the Engineering;* (2) *Chemicals;* (3) *Food;* (4) *Ceramics;* (5) *Textiles;* (6) *Drink Industries.*

KRAVIS, I. B., A. HESTON, R. SUMMERS, 1978a. "Real GDP *per capita* for more than One Hundred Countries", *Economic Journal*, June.

KRAVIS, I. B., A. HESTON, R. SUMMERS, 1978b. *International Comparisons of Real Product and Purchasing Power*, UN International Comparison Project: Phase II. Baltimore and London: Johns Hopkins Press.

MADDALA, G. S., 1977. *Econometrics*, London: McGraw-Hill.

MANNE, A. S., 1979. "The Use and Role of Models: Long-Term Energy Projections for the USA", International Conference on Energy Systems Analysis, Dublin: Commission of the European Communities and National Board for Science and Technology, October.

MCCARTHY, C., 1977. "Estimates of a System of Demand Equations using Alternative Commodity Classifications of Irish Data, 1953-1974", *The Economic and Social Review*, Vol. 8, No. 3.

MCCARTHY, C., 1979. "Should we Increase Energy Taxes?", Dublin Economics Workshop Policy: Conference Killarney, October.

NATIONAL PRICES COMMISSION, 1973. *The Pricing Policy of Coras Iompair Eireann*, Dublin: Occasional Paper, No. 10, July, Prl. 3364.

NIE, 1977. *National Income and Expenditure*, Dublin: Central Statistics Office.

NORDHAUS, W. D., 1976. "The Demand for Energy: An International Perspective", in *Proceedings of the Workshop on Energy Demand*, International Institute for Applied Systems Analysis, Laxenburg: Austria.

O'RIORDAN, W., 1972. "The Elasticity of Demand for Petrol in Ireland", (see also Geary and Arthur) *The Economic and Social Review*, Vol. 3, No. 3.

O'RIORDAN, W., 1976. "Consumer Response to Price and Income Changes", *Journal of the Statistical and Social Inquiry Society of Ireland*, Vol. XXIII, pp. 65-84.

RUANE, F., 1979. "Project Analysis and Industrial Employment in Ireland", *Quarterly Economic Commentary*, The Economic and Social Research Institute, June.

WALSH, B. M., 1979. "Our Changing Economic Prospects," Talk given to Rotary Club, Dublin, 18 June.

WEBB, M. G., 1978. *Policy on Energy Pricing*, Institute of Social and Economic Research, University of York. No. 252.

Appendix 1

Data used in the time-series studies

	(1) Total energy consumption '000 TOE	(2) Final deliveries '000 TOE	(3) GDP (by sector of origin at factor cost) 1970 £m
1950	2961	2602	n.a.
1951	3210	2959	,,
1952	3003	2685	,,
1953	3040	2700	,,
1954	3050	2643	,,
1955	3348	2986	,,
1956	3176	2816	,,
1957	2873	2458	,,
1958	2899	2420	877.9
1959	3391	2719	926.6
1960	3540	2949	972.5
1961	3535	2937	1012.5
1962	3678	3010	1049.4
1963	3891	3195	1083.0
1964	4132	3301	1138.9
1965	4314	3450	1152.7
1966	4568	3767	1169.7
1967	4934	3984	1229.2
1968	5050	4086	1311.5
1969	5340	4567	1366.7
1970	5750	4842	1399.7
1971	6780	5447	1481.5
1972	6820	5508	1546.0
1973	7083	5636	1648.1
1974	7209	5581	1683.4
1975	6787	5180	1692.0
1976	7039	5357	1746.0
1977	7512	5737	1842.0

Appendix 1 contd: *Data used in the time-series studies*

	(4) *Population*	*(5)* *Total energy consumption per head* *TOE* E_T	*(6)* *Final deliveries per head* *TOE* E_D	*(7)* *GDP per head* *1970 £* *GDP*
1950	2969	0.997	0.876	n.a.
1951	2961	1.084	0.999	n.a.
1952	2953	1.017	0.909	n.a.
1953	2949	1.031	0.916	n.a.
1954	1941	1.037	0.899	n.a.
1955	2921	1.146	1.022	n.a.
1956	2898	1.096	0.972	n.a.
1957	2885	0.996	0.852	n.a.
1958	2853	1.016	0.848	307.7
1959	2846	1.191	0.955	325.6
1960	2832	1.250	1.041	343.4
1961	2818	1.254	1.042	359.3
1962	2824	1.302	1.066	371.6
1963	2841	1.370	1.125	381.2
1964	2849	1.450	1.159	399.8
1965	2873	1.502	1.201	401.2
1966	2884	1.584	1.306	405.6
1967	2899	1.702	1.374	424.0
1968	2910	1.735	1.404	450.7
1969	2921	1.828	1.564	467.9
1970	2944	1.953	1.645	475.4
1971	2978	2.277	1.829	497.5
1972	3014	2.263	1.828	512.9
1973	3051	2.322	1.847	540.2
1974	3086	2.336	1.809	545.5
1975	3127	2.170	1.657	541.1
1976	3162	2.226	1.694	552.2
1977	3192	2.353	1.797	577.1

Appendix 1 contd.: *Data used in the time-series studies*

	(8) Real price of fuel and light August 1953 = 100 P_{FL}	(9) A general energy price index 1963 = 100 P_E
1950	104.6	106.4
1951	108.9	127.4
1952	101.7	116.8
1953	99.8	107.6
1954	99.8	107.4
1955	99.8	108.0
1956	111.6	118.3
1957	106.3	122.7
1958	99.6	113.9
1959	95.5	109.3
1960	93.5	102.4
1961	96.8	102.3
1962	97.1	102.6
1963	100.2	100
1964	94.5	96.7
1965	91.9	94.1
1966	91.8	91.9
1967	90.5	94.4
1968	90.5	93.7
1969	87.9	86.2
1970	87.9	81.0
1971	91.5	89.4
1972	92.8	87.6
1973	87.9	84.0
1974	115.2	122.3
1975	107.4	128.4
1976	106.7	130.4
1977	109.4	140.2

Sources: Column (1) 1968–1977: Energy Ireland; 1963–1968: OECD data checked by CSO; 1950–1963: J.L. Booth III; The data for overlapping years showed considerable discrepancies, such as that growth rates from the earliest two sources had to be used.

Column (2) 1973–1977: Energy in Ireland, Department of Industry Commerce and Energy; 1963–1972 OECD; 1950–1962 J.L. Booth II and III. The same problems were encountered as for (1).

Column (3) GDP from National Income and Expenditure 1975 Tables A4 and B4, updated from QEC.

The regressions used data from 1958—1977.
Source: Column (4) Reports on Vital Statistics

Columns (5), (6) and (7) are columns (1), (2) and (3) each divided by column (4).

Source: Column (8): Fuel and Light Consumer Price Index (August 1953 = 100) divided by All Items Consumer Price Index (August 1953 = 100). Irish Statistical Bulletins. This index unfortunately excludes transport fuels and is based on purchases by households only.

Column (9): Purchaser prices of the five major fuels were obtained (CPI data from CSO were used for coal, machine turf's price was used for turf, medium fuel oil's price was used for oil except for 1973—1977 when a combination of gasoline, fuel oil and gas oil was used, in the Dublin Gas Company's ordinary domestic tariff was used for gas, and revenue from electricity sales per unit sent out was used for electricity.) These prices were each based on 1963 = 100, then deflated by the All Items Consumer Price Index (1963 = 100). They were then each weighted by their fuel's share in total deliveries to give a single index. While broader in its coverage than (4), this index could and should be considerably improved with more detailed components.

Appendix 2

DETAILS OF THE TIME-SERIES ANALYSIS OF ENERGY DEMAND AND PROJECTIONS IN 1990 GIVEN IN CHAPTER 2

The time-series analysis covers the period 1958 to 1977. A feature of the energy market in Ireland is that price changes are largely determined by changes in world energy prices and taxation, that is, outside the normal internal market process. Expressing quantity as a function of price would give us a demand function. It is clear, however, that this demand relationship is shifting owing to income changes so that the addition of the income variable is required to correct for these shifts. Our task is to fit an equation which expresses energy demand as a function of income and price. We will briefly describe the data, the choice of functional form, selected results of the time-series analysis, and the time-series with a distributed lag in the price effect. Finally, there is a brief discussion of the projections.

The Data

Several problems arise in relation to the data. In the first place there is the problem that total energy consumption, though expressed in a common unit of energy equivalence, is neither homogeneous nor unchanging in its composition. For example, the last two decades have seen a decline in energy delivered to final buyers as a proportion of total energy consumed, in part due to the rising proportion of electricity. In seeking to overcome this some researchers (e.g., Nordhaus (1976)) use energy delivery to final buyers (final deliveries), one of the measures used in Chapter 1 and a measure also used here as a second option. This, however, does not overcome the problems arising from the different efficiencies with which the various fuels are consumed in their final uses, and the problems arising from the fact that the proportions of each fuel, the efficiencies and the final uses of each are all subject to change. Ideally we should construct a time-series of final useful energy, but it is not clear that the calculation of such a series would be worth the effort involved, especially when one considers the shortcomings of the available data for years up to the early 1970s. Selected results are given here using the series on total recorded energy consumption. Full results, including those based on final deliveries of energy, are given in Appendices 3 and 4.

For the explanatory variables, income is given by GDP by sector of origin at 1970 factor cost. Both energy consumption and GDP are expressed per head of population. For the other explanatory variable, price, there is the CPI for Fuel and Light published by the CSO which on division by the All Items price index, gives the relative or real price. This Fuel and Light price index excludes fuel for transport and is based on household consumption weighting patterns. An independent, and more general, price index (graphed in Figure 1) was constructed from purchase prices obtained from suppliers of the major types of fuel, weighted by the fuel shares of final deliveries, and expressed in real terms. Results, based on this latter index, are given in the Appendices 3 and 4. While this index covers a wider range of deliveries, it loses the detail which CPI can pick up. Clearly, neither price index is ideal.

To summarise, then, we have either total energy or final deliveries (in tonnes of oil equivalent per head) which we wish to express as a function of GDP (in 1970 £000s per head) and as a function of either the CPI for Fuel and Light or of a general energy price index (1963 = 100). Full data are given in Appendix 1.

The Choice of Functional Form

In choosing a particular form, one is to some extent predetermining the projected path. So, in addition to satisfying the data in terms of fit, the form must give plausible projections. A run down of the implied elasticities of some standard froms, given in Table A1 should help to guide one's choice.

Table A1: *Some standard functional forms and their elasticities*

Name	*Form*	*Elasticity*	*Path of elasticity as x increases (y non-negative)*	*Elasticity limits from x = 0 to x = ∞ (note*)*
1. Linear	$y = a + bx$	$\frac{bx}{y}$	rising	0, +1
2 Linear (negative)	$y = a - bx$	$\frac{-bx}{y}$	falling	0, $-\infty$
3 Semi-log	$y = a + b \ln x$	$\frac{b}{y}$	falling	∞, 0
4 Semi-log (negative)	$y = a - b \ln x$	$\frac{-b}{y}$	falling	0, $-\infty$
5 Semi-log (depend. variable)	$\ln y = a + bx$	bx	rising	0, ∞
6 Semi-log (negative) (depend. variable)	$\ln y = a - bx$	$-bx$	falling	0, $-\infty$
7 Double log	$\ln y = a + b \ln x$	b	constant	
8 Double log (negative)	$\ln y = a - b \ln x$	$-b$	constant	
9 Log reciprocal	$\ln y = a - \frac{b}{x}$	$\frac{b}{x}$	falling	∞, 0

Note* or from minimum x to maximum x for y non-negative, where relevant, and assuming a is positive.

As we have two independent variables, GDP and price, we have two elasticities to consider. Where GDP is concerned, cross country studies (Darmstadter 1971) and some time-series studies suggest an elasticity greater than unity for less developed countries declining to less than unity for developed countries, or to unity after correcting for efficiency in use (Brookes 1972). This implies that as a country develops the energy used in incremental output exceeds the average for all output, and energy intensiveness is growing. But, for a given level of technology and output composition, when the manufacture of all products has adopted the latest techniques, energy intensiveness stops growing. For our purposes we can reasonably assume that the elasticity, having been quite high, should be falling, or anyway in the long term, not rising. This assumption limits our interest to functional forms numbers 3 and 7, that is the semi-log or double log forms, even though the best, in terms of fit, is number 5 which implies a forever rising energy GDP elasticity. This would be quite unrealistic for anything but the short term, since it implies that energy's share will grow until it has absorbed the whole of GDP.

The price elasticity of demand for energy has received less attention except in the case of individual fuels. It may be safe to assume, however, that as the price of energy rises, the price elasticity will at least not decline in absolute terms. This suggests that the relationships between energy demand and price might be of the forms 2, 4, 6 or 8, namely, linear, both semi-log relations or double log. It should be noted, however, that those price elasticities with y in the denominator, forms 2 and 4, actually do decline in absolute terms in our applications. This occurs because y, or energy, is a function of two variables and GDP the dominant variable is making y rise.

Some Results of Time-Series Analysis without a lagged Price Effect

Selected results are given here using the official data series, that is total energy consumed, E_T and the real price of fuel, P_{FL}, that is the CPI for Fuel and Light deflated by the All Items Index. Full results are given in Appendix 3. The two equations, which satisfy the theoretical requirements and which are moderately satisfactory on statistical grounds, are as follows (t values in parentheses):

$$\underset{}{ln\, E_T} = \underset{(5.06)}{3.05} + \underset{(26.88)}{1.41}\, ln\, GDP - \underset{(2.29)}{0.30}\, ln\, P_{FL} \qquad \text{Adj } R^2 = 0.98 \quad DW = 1.52$$

GDP elasticity = 1.41
Price elasticity = –0.30

$$ln\, E_T = \underset{(13.66)}{1.99} + \underset{(26.66)}{1.41}\, ln\, GDP - \underset{(2.27)}{0.0030}\, P_{FL} \qquad \text{Adj } R^2 = 0.98 \quad DW = 1.52$$

GDP elasticity = 1.41
Price elasticity = –0.33

We see from these equations that the GDP elasticity is about 1.4 and the price elasticity about –0.3. In general, lower GDP elasticities and higher, more significant, price elasticities emerged when the energy deliveries series was used instead of the total energy series, used in the above.

The general energy price index, having more variation, gave a lower price elasticity, and was statistically more significant than the fuel and light price index. Using GDP at market prices gave a worse fit and lower elasticities than GDP at factor cost.

Turning from differences arising from the data to the question of equation specification, the plausible assumption, that the GDP elasticity falls in the long term, is not verified by the relatively short-term data at our disposal, as equations with just log of GDP, or log of GDP and price, showed bad Durbin-Watson measures. The asymptotic formulations suffer on the same grounds, though their asymptote levels are not outlandish, being at about Sweden's energy consumption per head or at the official (1978) "high forecasts" for Ireland in 1990. As mentioned above, equations implying growing GDP elasticity, with only energy in log form were most satisfactory. Ideally the search for an explanation of energy demand should be much broader than that attempted here, perhaps pursuing the energy implications of the incentives to capital intensive, hence possibly energy intensive production during the period. Furthermore, with the GDP elasticity so large, even the constant elasticity functions above will lead eventually to overprediction since an elasticity greater than unity implies that the share of energy in GDP will grow without limit as GDP rises. There is, however, one improvement which could make the model based on our existing data more realistic — that is, the incorporation of lagged price effects.

Time-series Analysis with a Distributed Lag in the Price Effect

It is realistic to assume that responses to energy price changes take a while to materialise. Habits are adjusted gradually and decisions to buy new equipment and the scrapping of old equipment will tend to take time. Eventually, technology itself will adjust. The full response to a price change, allowing for this time lag, should theoretically be larger than indicated by the results above, where responses are assumed to occur within the year. The following results bear this out.

We specified a geometric or Koyck-type lag on price so that the model became

$$E_t = a + b\,GDP_t + c\sum_{k=o}^{\infty} \alpha\,(1-\alpha)^k\,P_{t-k-1} + u_t$$

where t = time period in years,
$o < \alpha < 1$
expected $(u_t) = 0$
expected $(u_t\,u_{t+1})$ = some constant (σ^2) when i=o
expected $(u_t\,u_{t+1})$ = o when i≠o and
k = a backward time index.

Since α is less than unity, the term $(1-\alpha)^k$ declines as k increases, that is, the importance today, say, of any past price level declines as its distance from the present increases. The term $\sum_{k=0}^{\infty} \alpha(1-\alpha)^k$ is equal to unity so that the coefficient c gives the long-run price response. In the short run, k=o, the response is given by $c\alpha$ and applies to P_{t-1}. The mean lag is given by $(1-\alpha)/\alpha$ and can be viewed as the length of time elapsed for half the price response to take effect.[7] Appendix 6 outlines the estimation method.

Selected results are as follows, the full results being set out in Appendix 4. Using again the official data series and the constant elasticity formulation, we have:

$$\ell n\,E_{T,t} = \underset{(6.20)}{4.95} + \underset{(21.00)}{1.50}\,\ell n\,GDP_t$$

$$\underset{(4.10)}{-0.70} \sum_{k=0}^{\infty} 0.4\,(1-0.4)^k\,\ell n\,P_{FL,\,t-k-1}$$

Adj R^2 = .98	GDP elasticity = 1.50
DW = 1.82	Price elasticity (short run) = –.028
Mean lag = 1.50	Price elasticity (long run) = –0.70

7. Strictly speaking this is the definition of the median lag, given by: $-\ell n 2/\ell n(1-\alpha)$ (D. Gujarati, 1978, p. 282) but the two are quite close in value here.

and with just energy and GDP logged we have:

$$\ln E_{T,t} = \underset{(12.68)}{2.45} + \underset{(20.84)}{1.51} \ln GDP_t - \underset{(4.09)}{0.0071}$$

$$\sum_{k=o}^{\infty} 0.4\,(1-0.4)^k\, P_{FL,\, t-k-1}$$

Adj R^2 = .98	GDP elasticity = 1.51
DW = 1.83	Price elasticity (short run) = −0.31
Mean lag = 1.50	Price elasticity (long run) = −0.78

There is a considerable improvement in the Durbin-Watson measure compared with the previous two equations with no lags. As expected the short run elasticities are more or less the same as in the case with no lags, but the long run price elasticity is more than double the short run price elasticity. The model now suggests that a 10 per cent real rise in the Fuel and Light price index will lead to a seven per cent decline in total energy demand, in the long run, and that half this effect will take place within 1.5 years.

The model shows an improvement after the inclusion of lags in the response to price, and the results appear reasonable. There are, however, likely to be several separate lags when price changes. In the case of a price rise, the first source of lag will be the delay before consumers get round to incorporating energy saving measures into their existing appliances and habits. The next will be the delay in purchasing more efficient new appliances, until consumers feel they can scrap their original appliances. A longer lag would be the time elapsed between the occurrence of an energy price rise and the appearance of new more energy efficient appliances on the market. Our time-series covers only one major price rise, that of 1973, and the data covers only four years after that, though there was a major price-decline from 1958 to 1973 when opposite factors were at work. So if the model is picking up this longer lag, it is based on the periods of declining prices, and the responses to rises and falls in price may, or may not, be symmetrical. When price falls, one might not scrap efficient machines and buy inefficient ones, though one might buy a bigger, more energy intensive car.

Discussion of the Projections

All the projections to 1990 are given in Appendix 5. In particular the projections from the models with the distributed lag in the price effect are presented at the end of Chapter 2. In general the projections from the latter models are between 0 and 2 MTOE lower than projections from the models without the lagged effect, depending mainly on assumptions about future price rises. Though in the expected direction, this is quite a small change. The high and constant GDP elasticity is still the major force at work. Introducing the declining GDP elasticity assumption (in the form with GDP and price logged and the form with just GDP logged) gives markedly lower projections. Here, in Case IV, GDP elasticity has declined from 1.21 to about 0.8 by 1990. As mentioned (Chapter 3), the European Council adopted a "ratio" of 0.8 as the Community's objective for 1985 (Bremen, July 1978), the Community's ratio having been 1.0 and 0.66 for 1963-73 and 1970-76 respectively. In fact the Department of Industry, Commerce and Energy incorporates declining ratios in their official projections but these do not go below unity. As for our model's price elasticity, it is constant in the "all logs" form and it declines (in absolute terms) for most cases in the form with GDP and price logged and the form with just GDP logged, energy being in the denominator of the elasticity calculations. Only in the form with energy and GDP logged do we find a marked rise in the price elasticity in absolute terms, from −.78 (long term) in 1977 to −.93 for a 20 per cent price rise, to −1.17 for a 50 per cent price rise (Case III).

In summary then the projections show a wide range from about 18 MTOE down to about 11 MTOE, depending on assumptions. A 20 per cent real price rise and a 100 per cent GDP rise over 1977 to 1990 and constant GDP elasticity give an energy demand of about 18 MTOE. Replacing the above GDP growth by 70 per cent reduces energy demand to about 15 MTOE. Then allowing for a lagged price effect brings the projection down to 14 MTOE. Replacing the assumption of a constant GDP elasticity by the assumption that it declines, reduces the projection to about 12 MTOE. Higher prices obviously reduce the projections again.

Appendix 3

Results of time-series regressions of national energy consumption without a lagged price effect (see notes at end) 1958-1977

Equations	*Adj.* R^2	*DW*	*Elasticities* *GDP*	*Price*
All logs				
$\ell n\ E_T = 3.05 + 1.41\ \ell n\ GDP - 0.30\ \ell n\ P_{FL}$ (5.06) (26.88) (2.29)	.98	1.52	1.41	−0.30
$\ell n\ ET = 2.44 + 1.40\ \ell n\ GDP - 0.16\ \ell n\ P_E$ (8.46) (28.54) (2.69)	.98	1.48	1.40	−0.16
$\ell n\ E_D = -3.05 + 1.33\ \ell n\ GDP - 0.53\ \ell n\ P_{FL}$ (4.78) (23.89) (3.90)	.97	1.70	1.33	−0.53
$\ell n\ E_D = -4.16 + 1.31\ \ell n\ GDP - 0.29\ \ell n\ P_E$ (14.77) (27.38) (4.96)	.98	1.48	1.31	−0.29
Energy and GDP logged				
$\ell n\ E_T = 1.99 + 1.41\ \ell n\ GDP - 0.0030\ P_{FL}$ (13.66) (26.66) (2.27)	.98	1.52	1.41	−.33
$\ell n\ E_T = 1.85 + 1.41\ \ell n\ GDP - 0.0016\ P_E$ (23.73) (28.55) (2.74)	.98	1.46	1.41	−.22
$\ell n\ E_D = 1.94 + 1.34\ \ell n\ GDP - 0.0053\ P_{FL}$ (12.47) (23.59) (3.83)	.97	1.69	1.34	−.58
$\ell n\ E_D = 1.69 + 1.32\ \ell n\ GDP - 0.0028\ P_E$ (22.06) (27.33) (4.94)	.98	1.42	1.32	−.39
GDP and price logged				
$E_T = 4.52 + 1.33\ \ell n\ GDP - 0.18\ \ell n\ P_{FL}$ (3.37) (19.93) (0.64)	.96	.88	.99	−.08
$E_T = 4.25 + 2.33\ \ell n\ GDP - 0.12\ \ell n\ P_E$ (6.40) (20.63) (0.88)	.96	.88	.99	−.05
$E_D = 5.55 + 1.77\ \ell n\ GDP - 0.58\ \ell n\ P_{FL}$ (4.95) (18.12) (2.43)	.95	1.04	.98	−.32
$E_D = 4.40 + 1.75\ \ell n\ GDP - 0.33\ \ell n\ P_E$ (8.38) (19.61) (3.03)	.95	.89	.97	−.18
Linear				
$E_T = -0.19 + 5.48\ GDP - 0.005\ P_{FL}$ (0.81) (22.37) (1.92)	.96	1.31	1.34	−.23
$E_T = -0.38 + 5.48\ GDP - 0.003\ P_E$ (2.89) (24.49) (2.57)	.97	1.30	1.34	−.17
$E_D = 0.36 + 4.17\ GDP - 0.008\ P_{FL}$ (1.69) (19.41) (3.59)	.95	1.49	1.34	−.50
$E_D = 0.02 + 4.14\ GDP - 0.004\ P_E$ (0.24) (23.36) (4.98)	.97	1.30	1.33	−.34

Contd. *Results of time-series regressions of national energy consumption without a lagged price effect (see notes at end) 1958-1977*

Equations	*Adj. R^2*	*DW*	*Elasticities* *GDP*	*Prices*
GDP logged				
$E_T = 3.86 + 2.33 \ln GDP - 0.0018 P_{FL}$ (11.94) (19.78) (−0.62)	.96	.88	.99	−.08
$E_T = 3.80 + 2.33 \ln GDP - 0.0012 P_E$ (21.06) (20.47) (0.89)	.96	.87	.99	−.07
$E_D = 3.44 + 1.78 \ln GDP - 0.0058 P_{FL}$ (12.70) (17.96) (2.39)	.95	1.04	.99	−.35
$E_D = 3.19 + 1.76 \ln GDP - 0.0031 P_E$ (22.24) (19.49) (2.99)	.95	.87	.98	−.24
Energy logged				
$\ln E_T = -0.47 + 3.30\ GDP - 0.0049 P_{FL}$ (3.71) (25.53) (3.50)	.97	1.89	1.91	−.53
$\ln E_T = -0.67 + 3.28\ GDP - 0.0026 P_E$ (10.35) (30.09) (4.69)	.98	1.95	1.89	−.36
$\ln E_D = -0.38 + 3.12\ GDP - 0.0071 P_{FL}$ (2.82) (22.39) (4.77)	.96	2.05	1.80	−.78
$\ln E_D = -0.68 + 3.09\ GDP - 0.0037 P_E$ (11.01) (29.62) (7.10)	.98	1.98	1.78	−.52
Asymptotic without price				
$\ln E_T = 1.887 - 0.582 \frac{1}{GDP}$ (32.37) (23.72) Asymptote = 6.55 TOE per head	.97	.85	1.01	n.a.
$\ln E_D = 1.5737 - 0.54 \frac{1}{GDP}$ (23.32) (18.91) Asymptote = 4.8 TOE per head	.95	.61	.94	n.a.
Asymptotic forms with price				
Form $E = P^{\gamma} e^{\alpha + \beta/GDP}$				
$\ln E_T = 2.4094 - 0.1123 \ln P_{FL}\ \ 0.5866 \frac{1}{GDP}$ (3.49) (0.76) (23.04) Asymptote = 6.57 TOE/head (1977) 6.44 TOE/head for 20% price rise 6.28 TOE/head for 50% price rise	.97	.93	1.02	−.11
$\ln E_D = 3.2538 - 0.3611 \ln P_{FL} - 0.5536 \frac{1}{GDP}$ (4.60) (2.39) (21.25) Asymptote = 4.75 TOE/head (1977) 4.45 TOE/head for 20% price rise 4.10 TOE/head for 50% price rise	.96	1.08	.96	−.36
$\ln E_T = 2.1788 - 0.0623 \ln P_E - 0.5842 \frac{1}{GDP}$ (6.30) (0.86) (23.52) Asymptote = 6.50 TOE/head (1977) 6.42 TOE/head for 20% price rise 6.33 TOE/head for 50% price rise	.97	.92	1.01	−.06

Results of time-series regressions of national energy consumption without a lagged price effect (see notes at end) 1958-1977

Equations	*Adj. R^2*	*DW*	*Elasticities* *GDP*	*Price*
$\ell n\, E_D = 2.5040 - 0.1984\, \ell n\, P_E - 0.5460\, \frac{1}{GDP}$ (7.35) (2.77) (22.30) Asymptote = 4.59 TOE/head (1977) 4.42 TOE/head for 20% price rise 4.23 TOE/head for 50% price rise	.96	.91	.95	−.20
Form: $E = e^{\alpha + \beta/GDP + \gamma P}$				
$\ell n\, E_T = 1.7775 + 11.3280\, \frac{1}{P_{FL}} - 0.5861\, \frac{1}{GDP}$ (11.66) (0.78) (23.17) Asymptote = 6.56 TOE head (1977)	.97	.93	1.02	−.10
$\ell n\, E_D = 1.2252 + 36.1058\, \frac{1}{P_{FL}} - 0.5521\, \frac{1}{GDP}$ (7.89) (2.43) (21.41) Asymptote = 4.74 TOE head (1977)	.96	1.08	.96	−.33
$\ell n\, E_T = 1.8221 + 6.6405\, \frac{1}{P_E} - 0.5830\, \frac{1}{GDP}$ (19.27) (0.87) (23.57) Asymptote = 6.48 TOE head (1977)	.97	.93	1.01	−.05
$\ell n\, E_D = 1.3677 + 21.1026\, \frac{1}{P_E}\ 0.5420\, \frac{1}{GDP}$ (14.77) (2.84) (22.38) Asymptote = 4.56 TOE head (1977)	.96	.95	.94	−.15
Form: $E = e^{\alpha + \beta/GDP + \gamma/P}$				
$\ell n\, E_T = 2.0037 - 0.5869\, \frac{1}{GDP} - 0.0011\, P_{FL}$ (11.84) (22.89) (0.74) Asymptote = 6.58 TOE/head (1977) 6.42 TOE/head for 20% price rise 6.19 TOE/head for 50% price rise	.97	.93	1.02	−.12
$\ell n\, E_D = 1.9540 - 0.5550\, \frac{1}{GDP} - 0.0036\, P_{FL}$ (11.23) (21.06) (2.33) Asymptote = 4.77 TOE/head (1977) 4.41 TOE/head for 20% price rise 3.92 TOE/head for 50% price rise	.96	1.07	.96	−.39
$\ell n\, E_T = 1.9531 - 0.5854\, \frac{1}{GDP} - 0.0006\, P_E$ (19.93) (23.40) (0.84) Asymptote = 6.50 TOE/head (1977) 6.40 TOE/head for 20% price rise 6.25 TOE/head for 50% price rise	.97	.91	1.01	−.08
$\ell n\, E_D = 1.7845 - 0.5499\, \frac{1}{GDP} - 0.0018\, P_E$ (18.36) (22.15 (2.71) Asymptote = 4.61 TOE/head (1977) 4.38 TOE/head for 20% price rise 4.05 TOE/head for 50% price rise	.96	.88	.95	−.26

Notes:

All data given in Appendix 1.

E_T = Total energy consumption, TOE per head

E_D = Final deliveries of energy, TOE per head

GDP = GDP by sector of origin, £ 1000's per head, 1970 prices

P_{FL} = Consumer price index for Fuel and Light deflated by All Items index (excludes petrol).

P_E = Price index for all energy delivered, deflated by All Items index

t values in parentheses

Durbin-Watson test: the 5 per cent significance points of d_l and d_u are 1.100 and 1.54 respectively for two independent variables, and 1.20 and 1.41 for one independent variable.

Elasticities are calculated for 1977 where relevant.

The correlation coefficient for GDP and P_{FL} is 0.34 and for GDP and P_E is 0.26.

Appendix 4: *Time series regressions with geometric lags in the price response. 1958-1977 (See notes at end of table)*

Equations	*Mean lag*	*Adjusted R^2*	*Durbin-Watson*	*Elasticities* GDP	*Price (long-run)*	*Price (short-run)*
All logs						
$\ln E_{T,t} = 4.95 + 1.50 \ln GDP_t - 0.70 \sum_{k=0}^{\infty} 0.4\,(1-0.4)^k \ln P_{FL,\,t-k-1}$ (6.20) (21.00) (4.10)	1.50	.98	1.82	1.50	−0.70	−0.28
$\ln E_{T,t} = 3.21 + 1.50 \ln GDP_t - 0.32 \sum_{k=0}^{\infty} 0.49\,(1-0.49)^k \ln P_{E,\,t-k-1}$ (9.63) (25.00) (4.60)	1.02	.98	1.80	1.50	−0.32	−0.16
$\ln E_{D,t} = 6.93 + 1.38 \ln GDP_t - 1.20 \sum_{k=0}^{\infty} 0.34\,(1-0.34)^k \ln P_{FL,\,t-k-1}$ (8.47) (19.25) (6.86)	1.92	.98	2.07	1.38	−1.20	−0.41
$\ln E_{D,t} = 3.57 + 1.37 \ln GDP_t - 0.46 \sum_{k=0}^{\infty} 0.51\,(1-0.51)^k \ln P_{E,\,t-k-1}$ (10.79) (23.09) (6.75)	0.94	.98	1.70	1.37	−0.46	−0.24
Energy and GDP logged						
$\ln E_{T,t} = 2.45 + 1.51 \ln GDP_t - 0.0071 \sum_{k=0}^{\infty} 0.4\,(1-0.4)^k P_{FL,\,t-k-1}$ (12.68) (20.84) (4.09)	1.50	.98	1.83	1.51	−0.78	−0.31
$\ln E_{T,t} = 2.06 + 1.51 \ln GDP_t - 0.0029 \sum_{k=0}^{\infty} 0.51\,(1-0.51)^k P_{E,\,t-k-1}$ (22.47) (25.00) (4.55)	0.94	.98	1.79	1.51	−0.41	−0.21
$\ln E_{D,t} = 2.63 + 1.40 \ln GDP_t - 0.0122 \sum_{k=0}^{\infty} 0.34\,(1-0.34)^k P_{FL,\,t-k-1}$ (13.33) (19.15) (6.82)	1.92	.98	2.09	1.40	−1.33	−0.46
$\ln E_{D,t} = 1.89 + 1.40 \ln GDP_t - 0.0043 \sum_{k=0}^{\infty} 0.53\,(1-0.53)^k P_{E,\,t-k-1}$ (20.31) (22.79) (6.55)	0.88	.98	1.67	1.40	−0.60	−0.32

Contd.

Equations	*Mean lag*	*Adjusted* R^2	*Durbin-Watson*	*Elasticities* *GDP*	*Price (long-run)*	*Price (short-run)*
GDP and price logged						
$E_{T,t} = 10.68 + 2.84 \ln GDP_t - 1.459 \sum_{k=0}^{\infty} 0.295\,(1 - 0.295)^k \ln P_{FL,\,t-k-1}$ (5.43) (16.78) (3.45)	2.39	.97	1.47	1.21	−0.62	0.18
$E_{T,t} = 7.01 + 2.76 \ln GDP_t - 0.661 \sum_{k=0}^{\infty} 0.357\,(1 - 0.357)^k \ln P_{E,\,t-k-1}$ (8.53) (19.96) (3.84)	1.80	.98	1.42	1.17	−0.28	−0.10
$E_{D,t} = 12.30 + 2.07 \ln GDP_t - 2.025 \sum_{k=0}^{\infty} 0.286\,(1 - 0.286)^k \ln P_{FL,\,t-k-1}$ (8.47) (16.64) (6.49)	2.50	.98	1.71	1.15	−1.13	−0.32
$E_{D,t} = 6.48 + 1.996 \ln GDP_t - 0.752 \sum_{k=0}^{\infty} 0.424\,(1 - 0.424)^k \ln P_{E,\,t-k-1}$ (11.54) (20.48) (6.43)	1.36	.98	1.38	1.11	−0.42	−0.18
GDP logged						
$E_{T,t} = 5.46 + 2.86 \ln GDP_t - 0.015 \sum_{k=0}^{\infty} 0.295\,(1 - 0.295)^k P_{FL,\,t-k-1}$ (11.69) (16.71) (3.46)	2.39	.97	1.47	1.21	−0.69	−0.20
$E_{T,t} = 4.61 + 2.79 \ln GDP_t - 0.006 \sum_{k=0}^{\infty} 0.367\,(1 - 0.367)^k P_{E,\,t-k-1}$ (21.18) (19.89) (3.77)	1.73	.98	1.40	1.18	−0.36	−0.13
$E_{D,t} = 5.01 + 2.10 \ln GDP_t - 0.02 \sum_{k=0}^{\infty} 0.295\,(1 - 0.295)^k P_{FL,\,t-k-1}$ (14.85) (16.99) (6.48)	2.39	.98	1.72	1.17	−1.22	−0.36
$E_{D,t} = 3.76 + 2.04 \ln GDP_t - 0.007 \sum_{k=0}^{\infty} 0.433\,(1 - 0.433)^k P_{E,\,t-k-1}$ (24.18) (20.15) (6.21)	1.31	.98	1.34	1.13	−0.54	−0.23

Contd.

Equations	*Mean lag*	*Adjusted R2*	*Durbin-Watson*	*GDP*	*Elasticities Price (long-run)*	*Price (short-run)*
Energy logged						
$\ln E_{T,t} = \underset{(3.47)}{1.60} + \underset{(7.63)}{2.60}\, GDP_t - \underset{(4.50)}{0.0228} \sum_{k=0}^{\infty} 0.11\,(1-0.11)^k\, P_{FL,\,t-k-1}$	81.	.98	1.52	1.5	−2.50	−0.27
$\ln E_{T,t} = \underset{(7.84)}{-0.56} + \underset{(24.4)}{3.28}\, GDP_t - \underset{(5.43)}{0.0036} \sum_{k=0}^{\infty} 0.514\,(1-0.514)^k\, P_{E,\,t-k-1}$	0.9	.98	1.74	1.89	−0.50	−0.26
$\ln E_{D,t} = \underset{(2.73)}{0.496} + \underset{(16.97)}{2.88}\, GDP_t - \underset{(7.32)}{0.015} \sum_{k=0}^{\infty} 0.286\,(1-0.286)^k\, P_{FL,\,t-k-1}$	2.5	.98	1.84	1.66	−1.67	−0.48
$\ln E_{D,t} = \underset{(8.27)}{-0.574} + \underset{(23.10)}{3.07}\, GDP_t - \underset{(7.55)}{0.0047} \sum_{k=0}^{\infty} 0.586\,(1-0.586)^k\, P_{E,\,t-k-1}$	0.7	.98	1.69	1.77	−0.7	−0.39

Notes:

Estimation. The EAS (1975) computer program package used here uses the maximum likelihood search procedure in estimating:

$$E_t = a + \bar{a}\,(1-a)^{t-t_o} + b\,GDP_t + c \sum_{k=0}^{t-t_o-1} \alpha\,(1-\alpha)^k\, P_{t-k-1} + e_t$$

Where $\bar{a}$ is a parameter corresponding to the truncation remainder; the second term overcomes the problem that there is not an infinite number of observations.

Elasticities are calculated for 1977 where relevant.

Data as in Appendix 1

Appendix 5: *Projections to 1990. Energy demand in MTOE*

	Ordinary time series				*Time series with lagged price*			
	Cases				*Cases*			
	I	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*
1977-1990 GDP growth %	*70*	*70*	*70*	*100*	*70*	*70*	*70*	*100*
1977-1990 growth in real price of energy%	*0*	*20*	*50*	*20*	*0*	*20*	*50*	*20*
Functional Form								
All logs								
Total energy, E_T (using P_{FL})	15.58	14.76	13.82	18.42	15.44	13.93	12.28	17.65
Total energy, E_T (using P_E)	15.21	14.77	14.24	18.39	15.10	14.38	13.54	18.16
Final deliveries, E_D(using P_{FL})	11.54	10.47	9.29	12.91	10.70	9.02	7.33	11.21
Final deliveries, E_D (using P_E)	11.06	10.49	9.82	12.88	10.73	9.99	9.15	12.39
Energy & GDP logged								
Total energy, E_T (using P_{FL})	15.60	14.62	13.27	18.26	15.52	13.71	11.45	17.39
Total energy, E_T (using P_E)	15.21	14.57	13.64	18.17	15.17	14.16	12.81	17.94
Final deliveries, E_D (using P_{FL})	11.58	10.30	8.64	12.71	10.78	8.79	6.55	10.95
Final deliveries, E_D (using P_E)	11.07	10.25	9.13	12.62	10.82	9.78	8.44	12.18
GDP & price logged								
Total energy, E_T(using P_{FL})	12.08	11.96	11.81	13.29	12.40	11.69	10.81	13.30
Total energy, E_T (using P_E)	12.00	11.92	11.82	13.25	12.15	11.81	11.39	13.38
Final deliveries, E_D (using P_{FL})	9.24	8.86	8.38	9.87	9.04	8.06	6.86	9.24
Final deliveries, E_D (using P_E)	9.06	8.84	8.57	9.84	9.00	8.59	8.09	9.73

– Continued Appendix 5: *Projections to 1990. Energy demand in MTOE*

	Ordinary time series				*Time series with logged price*			
	Cases				*Cases*			
	I	*II*	*III*	*IV*	*I*	*II*	*III*	*IV*
1977-1990 GDP growth %	*70*	*70*	*70*	*100*	*70*	*70*	*70*	*100*
1977-1990 growth in real price of energy %	*0*	*20*	*50*	*20*	*0*	*20*	*50*	*20*
GDP logged								
Total energy, E_T (using P_{FL})	unacceptable Durbin-Watson				12.43	11.57	10.34	13.21
Total energy, E_T (using P_E)	(as also in the form: GDP and				12.18	11.70	11.00	13.29
Final deliveries, E_D (using P_{FL})	price logged, above)				9.12	7.96	6.29	9.15
Final deliveries, E_D (using P_E)					9.03	8.46	7.62	9.62
Linear								
Total energy, E_T (using P_{FL})	14.52	13.95	13.52	17.05	14.29	13.17	11.56	16.37
Total energy, E_T (using P_E)	14.35	14.06	13.62	16.99	14.35	13.80	13.00	16.97
Final deliveries, E_D(using P_{FL})	11.11	10.45	9.46	12.68	10.52	9.21	7.31	11.54
Final deliveries, E_D (using P_E)	10.84	10.40	9.72	12.61	10.76	10.14	9.24	12.50

Notes: E_T = total energy consumption, TOE per head
E_D = final deliveries of energy, TOE per head
P_{FL} = Fuel and Light price index deflated by All Items index
P_E = general energy price index deflated by All Items index

Appendix 6

ESTIMATION METHOD USED FOR THE MODEL WITH GEOMETRIC LAGS

Klein suggested a direct estimation method for this model. Maddala (1977) (p. 360) summarises it as follows: We have a model with a geometric or Koyck lag structure on the independent variable (price):

$$1. \quad y_t = \beta(1-\lambda) \sum_{i=0}^{\infty} \lambda^i x_{t-i} + u_t$$

It assumes that the response to price decays geometrically i.e., by factors λ, λ^2, λ^3 etc ($0<\lambda<1$). This assumes that after a price rise, for example, people might first replace their most inefficient or large energy using appliances (or habits) and make successively lesser adjustments gradually. The model can be broken down:

$$2. \; y_t = \beta(1-\lambda) \sum_{i=0}^{t-1} \lambda^i x_{t-i} + \beta(1-\lambda) \sum_{i=t}^{\infty} \lambda^i x_{t-i} + u_t$$

The first term can be computed from the actual observations for any given value of λ, the second term cannot because we do not have observations for x_0, x_{-1}, x_{-2}, et cetera. But writing $i-t=j$ (or $i=t+j$) the second term becomes

$$\beta(1-\lambda) \sum_{j=0}^{\infty} \lambda^{t+j} x_{-j} = \lambda^t \beta(1-\lambda) \sum_{j=0}^{\infty} \lambda^j x_{-j} = \lambda^t \eta_o = \lambda^t E(y_o)$$

by reference to 1. So η_o is a parameter corresponding to the truncation remainder, and can be called an "initial value parameter". The model can be written:

3. $y_t = \beta z_{1t} + \eta_0 z_{2t} + u_t$

where $z_{1t} = (1-\lambda) \sum_{i=0}^{t-1} \lambda^i x_{t-i}$

and $z_{2t} = \lambda^t$

The procedure for estimating λ and β are as follows: For each value of λ we construct the variables z_{1t} and z_{2t} then regress y_t on z_{1t} and z_{2t} and look at the residual sum of squares. We choose that value of λ for which this is a minimum. This is the maximum likelihood estimate of λ, and the corresponding values of β and η_o are the ML estimates of the parameters. It can be shown that the estimators for β and λ are consistent but that for η_o is not. The inapplicability of the Durbin-Watson statistic as a test for autocorrelation in certain distributed log models is well known. However, because Klein's method gives consistent estimates of β and λ, the Durbin-Watson statistic is applicable (Dhrymes 1971 p. 344).

The EAS (Econometric Analysis System) package uses this method, denoting λ by $(1-\alpha)$ and delaying the initial response to a price rise by one year.

Appendix 7

OTHER PRICE ELASTICITIES OF DEMAND FOR ENERGY

Given here are a few other calculations of effects of price changes on the demand for energy. First the evidence for Ireland is summarised, then a few interesting international studies are mentioned.

Price elasticities of demand in Ireland

	Year in which the elasticity applies	*Price elasticity*		*Source*
Fuel	1974	−0.57		McCarthy (1977)
Petrol	1974	−0.84		McCarthy (1977)
Fuel	1972	− .59		O'Riordan (1976)
Petrol	1972	−1.0		O'Riordan (1972)
Petrol	1968	−0.40	(long term)	Feeney (1979)
Petrol	1968	−0.03	(quarterly, short term)	Feeney (1976)
Petrol	1968	−0.155	(annual, short term)	Feeney (1976)

Fuel and power	1970	−0.55	(0.24)	Kravis (1978b)
Fuel and power	1973	−0.75	(0.18)	Kravis (1978b)
Electricity	1970	−0.74	(0.29)	Kravis (1978b)
Liquid fuels	1970	−0.82	(0.61)	Kravis (1978b)
Other fuels and ice	1970	−0.73	(0.47)	Kravis (1978b)

The countries comprise: Belgium, Colombia, France, Germany, Hungary, India, Iran, Italy, Japan, Kenya, Korea, Malaysia, Netherlands, Philippines, the UK and the USA. Standard errors in parentheses.

For a comprehensive list of studies undertaken before 1977 of price elasticities for energy, see: Report of the Working Group on Energy Elasticities, Energy Paper Number 17. Dept. of Energy, HMSO, Feb. 1977.

Elasticities in the table below for the US, reproduced from Hudson and Jorgenson (1978) indicate the changes in the relative quantities in which two inputs are used, caused by a change in their relative prices. The authors state:

> The numerical values of these elasticities can be interpreted as follows: a value of zero means that the two inputs are used in fixed proportions; a negative value means that there is a complementary relationship between the inputs, a rise in the price of one input is associated with reduced use of the second input; a positive value implies a substitution relationship, a rise in the price of one input leads to increased use of the other. Also, the greater the absolute value of the elasticity, the stronger the relationship or interaction between the inputs. The own elasticity of substitution will be negative; this simply implies that when the price of this input rises, demand for the input will decline.
>
> In agriculture, non-fuel mining, and construction there is a reasonably strong substitution relationship between energy and labor, and a substantial response of energy demand to energy price. In manufacturing, there are three strong interactions; energy and labor, and capital and labor are substitutes while energy and capital are complements. The commercial transportation sector exhibits complementarity between energy and capital and a significant own price elasticity of demand for energy. In the services, trade, and

Allen partial elasticities of substitution between inputs in the US

	INPUT Capital	Labour	Energy	Intermediate materials
Agriculture, non-fuel mining construction				
Capital	–1.7673			
Labour	0.3553	–2.5018		
Energy	–0.0591	1.4148	–29.6499	
Intermediate materials	0.6134	1.0442	0.5987	–0.8289
Manufacturing				
Capital	–3.1820			
Labour	1.1004	–1.6181		
Energy	–1.4156	1.8900	– 4.8410	
Intermediate material	0.0963	0.5072	– 0.4732	–0.2435
Commercial transport				
Capital	–1.4036			
Labour	0.1755	–1.0920		
Energy	–0.8577	–0.0574	–11.5998	
Intermediate materials	0.5747	1.1309	1.7739	–1.7267
Services, trade, communications				
Capital	1.6979			
Labour	1.0903	–0.8795		
Energy	1.2110	2.3065	–49.3616	
Intermediate material	0.0660	0.0440	– 1.8201	–0.0245

communications sector, there are four strong interdependencies: energy and capital, energy and labor, and capital and labor are substitutes while energy and intermediate materials are complements.

No such study has been undertaken for Ireland. We only know that there was a negative correlation between energy and numbers employed per unit of output in 8 of 10 major sectors, from 1962-1973.

Appendix 8

Comparison of costs of various fuels in different heating systems for domestic heating in Dublin, 5th February, 1980.

Price per unit of useful heat (p/kwh)

	Appliance							
	Open fire		*Enclosed stove*[1]	*Central heating boiler*	*Warm air systems*	*Electric storage heaters*	*Direct electric heaters*	*Flueless heater*
	Plain	*With high output back boiler*						
Coal	3.8	2.5	1.4	1.4				
Turf	2.4	1.6	0.9	0.9				
Briquettes	3.3	2.2	1.2	1.2				
Anthracite			1.8	1.8	1.7			
Towngas				3.4	3.7			2.5
Gas oil				2.0	2.1			
Kerosene				2.1	2.3			
Butane Propane				2.7				2.5
Electricity					3.1	3.1	4.2	

Note: 1 = or room heater with back boiler
Source: C. Ward, Institute for Industrial Research and Standards. These costs apply for a semi-detached house of $100m^2$ floor area. For other assumptions, apply to C. Ward.

Appendix 9

PRESS RELEASE FROM THE DEPARTMENT OF INDUSTRY, COMMERCE AND ENERGY

Report of Inter-Departmental Committee on Allocation of Kinsale Head Gas

Following proposals from the Dublin Gas Company in July 1977 for an allocation from the Kinsale Head natural gas find for distribution by that Company in the Dublin area the Minister for Industry, Commerce and Energy appointed an Inter-Departmental Committee consisting of representatives of his Department, the Department of Finance and the Department of Economic Planning and Development to consider the allocation for energy purposes of a major part of the Kinsale Head gas and to consider specifically the proposals of the Dublin Gas Company for an allocation of this gas.

The Inter-Departmental Committee have concluded their study of this matter and their report has been submitted to the Minister for Industry, Commerce and Energy. The main conclusions to the Report which the Minister, after careful consideration and consultation with his Government colleagues, accepts are:—

(i) natural gas should in general be allocated on the basis of commercial procedures and principles and other things being equal, on the basis of market prices. Considerations of national interest may, however, occasionally warrant a price less than the optimal commercial price.

(ii) The use of natural gas for base load electricity generation may not be the best use for natural gas and alternative uses should therefore be actively sought. However, subject to provision for interruptability, the natural gas for base load electricity generation is likely to continue for some considerable time. On the other hand, the use of natural gas for "peak shaving" electricity generation would be generally regarded as a prime use for the gas.

(iii) any alternative uses for the gas should be evaluated and compared in the first instance in the light of the gas price a project could bear, the minimum price being the cost to the ESB of replacing the gas and of any transportation costs.

(iv) The use of Kinsale gas by the Dublin Gas Company on the basis of the foregoing criteria would not be a reasonable financial proposition, and

(v) the pricing arrangements with the ESB in relation to its allocation of natural gas should be reviewed as soon as possible with a view to determining what would be an appropriate energy related price. The consideration of the price to be charged to the Cork Gas Company should also take into account its energy related value.

The Minister has directed that the future policy of Bord Gais Eireann should be in accordance with the foregoing principles. In particular, he has asked Bord Gais Eireann and the Industrial Development Authority to investigate the possibilities of obtaining alternative uses for the ESB's allocation of natural gas including industrial development and employment creation through new industries for which the availability of natural gas would be an important consideration.

The Minister also announces that due to his concern about the future of the town gas industry he proposes to arrange for a review of its operations.

10 April 1978.

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