# HOUSEHOLD ENERGY EXPENDITURES:

# POLICY RELEVANT INFORMATION FROM THE HOUSEHOLD BUDGET SURVEY

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Denis Conniffe is a Research Professor with The Economic and Social Research Institute. The paper has been accepted for publication by the Institute, which does not itself take institutional policy positions. Accordingly, the author is solely responsible for the content and the views expressed.

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**Denis Conniffe**



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# General Summary

## Energy Policy

Energy policy in Ireland has varied over time and it is probably fair to say it has largely been determined by the predominant problem of the moment. When world oil prices jumped dramatically in 1974 and again in 1979, there were fears that prices would remain high indefinitely and that oil was a rapidly depleting resource. Huge efforts were made to diversify away from oil, with active encouragement to burn coal and turf in the home and to use it for solid fuel central heating. Coal and gas burning power stations for electricity generation replaced oil fuelled stations. But as the years passed oil prices (in real terms) declined greatly from their peaks, predictions of the imminent depletion of oil reserves proved premature, to say the least, and energy cost did not prove a limiting constraint on Irish economic growth. In recent years there has been growing concern about adverse environmental impacts of the processing and consumption of energy. This has resulted, at both national and European Union level, in actions restricting uses of some fuels and agreement on measures to reduce carbon dioxide (and other greenhouse gas) emissions and the hypothesised consequent global warming.

In principle, energy policy could be focused on any of several, probably not entirely compatible, objectives or, perhaps more realistically, could seek a balance between them. The objectives could include: minimisation of national energy costs; maintaining maximum security of supply; minimising negative externalities, especially damage to the environment; safeguarding household welfare and perhaps even maintaining employment in regions very dependent on energy utilities. As already said, the environmental aspect seems currently dominant and the specifications of the Kyoto agreement, to which the EU is party, could already be considered to commit Ireland to attaining quite restrictive levels of carbon dioxide emissions by 2009-12. But measures to achieve environmental welfare could easily conflict with the other objectives. However, this paper will not try to address the formidable task of determining optimum energy policy. The paper is largely an elicitation of whatever information the Household Budget Survey can provide about key parameters and relationships in the household energy sector. This will at least provide some building blocks for future policy analysis.

## Household Energy and the Household Budget Survey

In 1994 there were 1.05 million households in the Republic with average household size of 3.28. This household sector obviously uses a lot of energy in total, but it is still just a portion of Irish energy consumption and it is as well to commence by placing that portion in perspective. Household energy use, defined as that required for power, light and heat in domestic dwellings, constituted some 28 per cent of national final energy demand. Other economic sectors consume more energy and The Economic and Social Research Institute (ESRI) has previously shown that, on present trends, the greatest increase in consumption will be attributable to private motor transport. But the household sector is still important. As regards greenhouse gases, for example, UK research has produced estimates of an average (per household in 1996) of 7.5 tonnes of carbon dioxide emissions from dwellings in Great Britain and a corresponding average of 16.7 tonnes for Northern Ireland (the much greater value largely due to lack of access to natural gas, which has a much lower carbon intensity than oil or solid fuels). Average carbon dioxide emissions from dwellings in the Republic can be taken to lie between these figures.

The Household Budget Survey is undertaken at seven year intervals, the most recent being that conducted between mid-1994 and mid-1995. It had a sample size of nearly eight thousand participating households and measured expenditures on a comprehensive range of household commodities, including fuels, as well as recording possessions of household durables and powered appliances. The principal fuels are – Piped Gas, Electricity, Coal, Turf, Oil and Liquefied Petroleum Gas (LPG). There are other minor components of household energy expenditures, such as candles, firelighters and kindling, but they are virtually negligible in overall expenditure terms. The survey also recorded the economic, educational, social and demographic characteristics of the households themselves, and also physical characteristics of the dwellings such as age, size, structural type, possession of a gas connection, etc. So household energy expenditure can be related to a wide range of explanatory factors. Changes over time can be investigated by comparing the survey with its predecessor of 1987.

## Findings and Conclusions

Energy expenditure averaged £15 per week, or 4.8 per cent of total household expenditure, with expenditure on electricity, being over 40 per cent of the total. Between 1987 and 1994 energy expenditure increased by 5.3 per cent in real terms, compared with a 15.5 per cent increase in total household expenditure, but this masks more dramatic changes between sectors and fuel shares. For urban households energy expenditure increased by just a little over 1 per cent, while for rural households it increased by 12 per cent. Expenditure on Gas rose by 97 per cent and on Oil by 110 per cent (86 per cent in urban and 153 per cent in rural areas), while expenditures on coal, turf and LPG fell substantially. These patterns resulted from the increased prevalence of central heating, the growth of the natural gas industry and disapproval of "dirty" fuels. In 1987 half of all houses possessed full central heating and by 1994 that had increased to over two-thirds. However, this is certainly not yet the saturation level and the scope for further increase is evident from the 87 per cent possession rate in Northern Ireland dwellings in 1996.

This increase in central heating was greater for rural than for urban households (a catching up process) and this, along with the unavailability of piped gas in rural areas, explains the huge increase in rural oil demand. In urban households new central heating installations (and switches from solid fuel systems, which declined substantially in number) were split between gas and oil systems. In 1987, 5.4 per cent of households had gas fuelled central heating, while 13.3 per cent had an oil based system and by 1994 the corresponding figures were 21.1 per cent and 24.6 per cent respectively. The legislative restrictions on smoky fuels in urban areas also had important effects. Coal expenditure declined between 1987 and 1994 by 39 per cent in urban, compared with 14 per cent in rural areas, while turf, because briquettes had been exempted from the legislation, declined by only 5 per cent in urban, compared with 15 per cent in rural areas. There was another "catching up" process of rural to urban as regards possession of electrically powered consumer durables and this was reflected in the relative increases in electricity expenditures – up 29 per cent for rural as compared with 3 per cent for urban households.

In spite of the increases between 1987 and 1994, overall levels of possession of central heating and of some consumer durables were still, as mentioned earlier, well short of saturation in the latter year. This, in conjunction with the high level of new household formation of recent years, which can be expected to continue for the years immediately ahead, suggests that these trends of increasing overall energy consumption and demand for oil and gas will continue. Of course, if saturation approaches, the rate of new household formation will become the key determinant of the household sector's demands for oil, gas and electricity. The balance between future demand for oil and gas will depend, not only on relative price, but on household location and availability of gas connection.

Frequency of gas connection was related to type of housing in the 1994-95 survey. The higher frequencies occurred for Semi-detached (+Terraced) houses (32 per cent) and for apartment blocks (20 per cent). For houses built between 1918 and 1970, the incidence of gas connection exceeded a third. This fell to about 15 per cent for subsequent house construction up to 1985, but increased again to 24 per cent for houses built between then and the survey. Gas connected houses had a higher proportion of central heating (84 per cent) than had houses without gas connection (68 per cent). In the former, the system of central heating was predominantly (91 per cent) gas, while in the latter, oil fuelled systems were most frequent (50 per cent). However, since only a minority of houses were gas connected (26.3 per cent of urban or 17.9 per cent of all), oil based systems were more frequent (38 per cent) than gas fuelled systems (29 per cent) in urban areas. Frequency of central heating was strongly related to type of housing. Of detached and semi-detached houses, 77 per cent and 72 per cent possessed central heating, as did 50 per cent of households living in large apartment blocks. For households living in small apartment blocks the percentage fell to 27 per cent and was lower still for bed-sitters and other accommodation. Oil was by far the most frequent heating fuel in detached houses (rural are included, of course), while gas was slightly more frequent than oil in semi-detached houses (33 per cent as compared to 31 per cent). Only in apartments was electric central heating relatively frequent. It was the commonest system (50 per cent) for households living in small apartment blocks and the second most frequent for households living in large apartment blocks (33 per cent), or converted apartments (25 per cent), following oil systems in both cases (with 37 per cent and 41 per cent respectively). As might be expected, older houses had lower possession of central heating, while about 80 per cent of dwellings dating from 1960 to 1984 now have it. Since 1986, few dwellings have been constructed without it.

Although possession of central heating has become more prevalent in all social classes, it is still income related. There is over 90 per cent possession in the "higher" social groups such as "higher professional" and "self employed", falling to around 50 per cent at the "lower" end for such as unskilled manual. Perhaps more interestingly, the higher social groups favour oil or gas – the clean, convenient, fuels. Other fuels and backboiler based systems become more common with lower social groups.

Average energy expenditure by rural households exceeded that for urban households, although rural incomes were somewhat lower and the "catching up" as regards central heating and possession of electrically powered consumer durables had not quite achieved equality. The explanation does not seem to lie with differences in the fuel mix, although this did vary considerably between urban and rural because of the restrictions on smoky fuels in the former and the unavailability of gas in the latter. The greater frequency of older houses in rural areas and the far greater frequency of detached houses seems to increase the expense of home heating, although there may be other possible explanations such as greater occupancy of rural homes during the day.

Quantification of the relationship between household expenditures on fuels and income is necessary for certain purposes (for example, for detailed forecasting) and can be achieved by estimating income elasticities. The income elasticity of energy is defined as the percentage increase in electricity expenditure, given a one per cent increase in income. The elasticities of fuels are defined similarly. Electricity, the most important fuel in terms of overall expenditure, was found to have an income elasticity of .35. A doubling of income (assuming price unchanged) would increase electricity consumption by 35 per cent. The income elasticities of gas and oil were relatively high, at .75 and 1.05 respectively. Energy is usually thought of as a necessity, which normally implies a low, but positive, income elasticity, as in the case of electricity. The reason for the high figures for gas and oil is that possession of a clean system of central heating is very definitely an aspiration of every household as income increases. Gas is largely a central heating fuel and oil (within households) is almost entirely so. On the other hand, for coal, turf and LPG, expenditures fall with higher incomes, so that the income elasticities are all negative, being -.29, -.30 and -.32 respectively. The income elasticity for overall energy was .25. Household size elasticities (how energy consumption changes with family numbers) were also investigated, but were usually small and certainly so for overall energy.

## Relevance for Energy Policy

Taking the view that the environmental aspect should dominate, because of the concern about global warming and the Kyoto agreement, future carbon dioxide emissions are of great interest. The recent ESRI Medium-Term Review of the Irish economy forecasts the number of households increasing by 45,000 per year for a decade and also predicts a doubling of disposable income over the same period. Because of the low income elasticity, a doubling of income would imply only a 25 per cent increase in energy consumption. However, taken with the increase in number of households, the sector's energy use would grow by around 80 per cent. It may well be plausible that future household size will be smaller, on average, than currently, but hardly by enough to make much difference, given the small size elasticity found.

The 80 per cent increase in energy consumption need not translate into a corresponding increase in emissions. All fuels, except for electricity, contribute directly to carbon dioxide emissions with the fossil fuels – oil, coal and turf – having the higher concentrations and, as the UK emissions figures show, this can make a big difference. However, except for oil, consumption of fossil fuels has been shown to decline with income and also, as has been mentioned, almost all newly constructed dwellings embody central heating, predominantly gas or oil based systems. So as regards increased direct contributions to carbon dioxide emissions, attention can effectively be confined to oil and gas. Actually, the validity of these statements could depend on the relative prices of fuels remaining constant and the subject of price changes will be returned to.

Gas, with its lower carbon dioxide emissions, is an alternative central heating fuel when gas connection is available. For households within areas served by the existing gas grid, availability may still depend on the type of building containing, or constituting, the dwelling. In apartment blocks, as has been pointed out, not only oil, but also electrical, central heating systems were more frequent in 1994-95 than gas systems. More importantly, availability depends on spatial location. Access to the gas grid is not available in areas currently considered rural, but it is probably true to suppose that most new dwelling construction will occur as new estates of houses or apartments. If these estates are close to the existing gas grid, as they will be if they are extensions to current urban areas, connection should not be a difficulty. The exploitation of the new gas field off County Mayo will probably add considerably to the grid, especially if the potential Northern Ireland market is accessed, and make piped gas available to some towns currently without access. Even in the case of a town, distant from existing grids, a profit motivated gas utility could be expected to invest in the necessary grid extension if the potential sales volume justified it.

However, even the primacy of the environmental objective would not necessarily warrant State subsidisation of grid extensions in cases where the industry would not otherwise undertake them. LPG also has relatively low carbon dioxide emissions and subsidies or other interventions could counter the tendency, already mentioned, for it to be substituted by oil as incomes increase. Where safety considerations and constructional constraints, not lack of gas main proximity, is the barrier to connection, regulating for larger apartment blocks, or grant aiding provision of regulation compliant gas heating in smaller blocks might be possibilities. But all interventions to encourage gas consumption could conflict with other policy objectives and perhaps State involvement in gas promotion should go no further than ensuring that the gas industry is efficient and competitive. The industry itself could then be expected to extend the grid to its economic optimum and to defend its own interests with the house/apartment construction industry. Other State efforts might be devoted to reducing emissions through encouraging efficient energy use and conservation measures, such as insulation etc. However, previous ESRI research found the uptake of reasonably straightforward, and apparently economically attractive, conservation measures to be disappointing, although some Northern Ireland findings are more positive.

Turning to indirect contributions to emissions, household electricity use does not contribute to the problem directly, but the generation of that electricity will do so, with the volume of carbon dioxide greatest if the power stations employ fossil fuels. The household sector does make a substantial contribution to demand for electricity as it is the fuel on which household expenditure is greatest (over 40 per cent of household energy expenditure). Assuming new household formation at the rate already specified and a doubling of incomes, the income elasticity of .35 suggests an 95 per cent increased electricity demand. However, this elasticity largely derives from increases in the household stocks of electricity powered appliances and saturation is conceivable. The 1994-95 situation was still well short of saturation, but stocks will have increased since then and a doubling of income over the next decade will probably leave very few households without all the current electrically powered household appliances well before 2010. So an estimate of an 80 per cent increase seems more plausible. But it might underestimate. Saturation may not be inevitable, because there must be some likelihood that new electricity powered appliances will be invented and marketed. Nor can it be known in advance how energy intensive they might be.

If reduction of carbon dioxide emission levels is approached through a strategy of switching fossil fuel powered electricity generation to gas powered, some increase in electricity price would result and this would decrease household consumption somewhat, but probably by very little. Most studies have found electricity demand to be insensitive to price, because household electricity demand derives from possession of appliances, for most of which there is no substitute fuel. However, this is not a topic on which the Household Budget Survey (HBS) is particularly informative, as prices, unlike incomes, do not vary between households.

Discussing price marks an appropriate point to leave the emissions policy objective and briefly consider the implications of the HBS results for the other objectives. The objective of minimisation of national energy costs has to be interpreted in the context of possible changes in world fuel prices and patterns of supply. This implies switching between fuels if relative prices change substantially. As already mentioned, after the oil price hikes of 1974 and 1979, great efforts were made to diversify away from oil, towards coal and turf and gas. (Grants were even paid to install fireplaces and chimneys in houses constructed without them in the preceding cheap oil era.) The subsequent fall in oil prices and concern about polluted urban air changed all that again. Nowadays, the household sector has now become very dependent on gas, oil and electricity. If the emissions policy objective is truly the supreme priority, the dependency on gas will become ever greater through its direct use in households and for the generation of household electricity. In these circumstances, the consequences of a big gas price hike could be just as economically damaging as were the oil price increases in the past.

Similar comments apply to maintaining maximum security of supply, although further gas finds around the Irish coast might help in this regard. As regards household welfare, it is a quite tenable argument that providing income support where necessary and promoting efficiency and competition between the various fuel suppliers is the best strategy. The objective of maintenance of employment in some energy related areas (Bord Na Móna, for example), can have little value in itself in current Irish circumstances of labour shortages, although some such maintenance might follow from a wish to retain a diversity of energy sources. Here again the issue of the priorities of the objectives of minimising cost and security of supply arise. Much hangs on whether the specifications of the Kyoto agreement are to be taken as truly binding, or as already unattainable targets. Although it would be much easier to assess the implications of findings from the Household Budget Survey (or any other source) for energy policy if priorities were clear, it cannot be the role of this paper to formulate such priorities.

# 1. INTRODUCTION

## 1.1 Energy and the Economy

Long before global warming was perceived as a threat to humanity's future, the topics of energy provision and consumption have been of considerable, and sometimes overwhelming, interest to the Irish consumer. This is not only because the citizen must purchase some energy directly in the form of gas, electricity or other fuels, but also because energy is an essential input into the production of almost all other goods and services and its price feeds through to theirs. Indeed, for industries where the energy input is particularly important, price changes can seriously affect competitiveness, especially since Ireland depends on imports for by far the greatest part of its primary energy. In consequence, even the employment of some citizens could be affected by shocks to world energy prices. So in the past, public interest in energy policy hit high points when world oil prices jumped dramatically in 1974 and 1979-80. Fears that prices would remain high indefinitely and that oil reserves were a rapidly depleting resource led to debates centring around how to mitigate the damage to living standards and how to diversify the fuel mix away from oil. These themes are evident in publications of the period; for example, Nichol (1978-79) and Scott (1980).

Oil prices (in real terms) soon declined greatly from their peaks, predictions of the imminent depletion of fossil fuels proved premature, to say the least, and energy cost did not prove a limiting constraint on Irish economic growth. However, energy and its price are still important through input costs to the productive sector and expenditures on commodities by the household sector. But there has also been an ever growing concern about adverse environmental impacts of the processing and consumption of energy. This has resulted, at both national and European Union level, in actions restricting uses of some fuels and agreement on measures that could have far reaching consequences. Perhaps the most crucial relate to carbon dioxide (and other greenhouse gas) emissions and the hypothesised consequent global warming. Since the EU is party to the Kyoto agreement, Ireland could already be considered committed to attaining quite restrictive levels of such emissions by 2009-12. In the context of rapid economic growth in recent years and our projected level of future growth, these imply substantial difficulties. The problems and the policy measures that might be employed have been discussed in Conniffe, Fitz Gerald, Scott and Shortall (1997). It is clear that, even if motivations have changed somewhat, the relationship between energy use and economic growth remains of compelling interest.

Irish studies of the energy to economic activity relationship have been very largely conducted at aggregate, or economy wide, rather than sectoral level. These studies have also tried to encapsulate the complex interactions of energy with other factors into relationships between just a few summary statistics. For example, Scott (1978-79) related total national energy consumption to GDP and energy price, using data over 20 years to 1977. Conniffe and Scott (1990) considered the component fuels making up total energy, but again at aggregate annual level, employing data over 28 years from 1960 to 1987. Conniffe *et al.* (1997) repeated these analyses using the extra data accumulated up to 1995. However, as is discussed in Conniffe (1993), the aggregate relationship of energy consumption to GDP is not at all straightforward and seems to be evolving with time. One reason is that different relationships could be expected to hold in different sectors. Increased output of the manufacturing sector, associated with national economic growth, could drive an increasing energy demand. One would also expect a positive relationship to hold in the services sector, but hardly an identical one. The transport and household sectors could show yet different relationships, while output in the agricultural sector could even be stagnant. Different relationships within sectors could be compatible with a stable overall average relationship between energy and GDP, if the relative importance of the sectors remained unchanged. But the structure of the Irish economy has evolved enormously since the 1960s and this is certainly a cause of difficulties with the aggregate relationship.[1]

Ideally, energy consumption should be studied within each major economic sector and the overall picture deduced from the findings. However, the difficulty of obtaining satisfactory data for some sectors has deterred any comprehensive approach along these lines. In their study on possible costs of controlling greenhouse gases, Conniffe *et al.* (1997) did separate out the transport sector, because of the special importance of vehicle emissions, but all other sectors were aggregated. As regards energy in the household sector, with which this publication is concerned, the Central Statistics Office's Household Budget Survey (HBS) does contain all the required data for the period in which the survey is conducted. Also, the Central Statistics Office, subject to guarding respondents' anonymity, has now adopted a policy of making the basic data from its recent surveys available to researchers. Previously only aggregated level data were available. So it is now opportune to investigate energy in the household sector in detail. Unfortunately, the Household Budget Survey it is only conducted at seven year intervals, with the most recent being in 1994-95.[2] As

[1] There can be other factors causing instability in the aggregate energy to GDP relationship besides the changing sectoral composition of the economy. These are discussed in Conniffe (1993).

[2] The Central Statistics Office intend reducing the intervals between surveys to five years.

will be discussed in later chapters, this does limit the deductions that can be drawn from the survey, but it is still the best single source available.

## 1.2 Energy, the Household Sector and the Household Budget Survey

In 1994-95 there were 1.05 million households in the Republic with average household size of 3.28. This household sector obviously uses a lot of energy in total, but it is still just a portion of Irish energy consumption and it is as well to commence by placing that portion in perspective. Figures quoted will continue to refer to the survey period of 1994-95. Ireland's primary energy requirement was approximately 11 million tonnes of oil equivalent (TOE), which included fuels employed in generating electricity. Most imported coal was used for this purpose as was most natural gas and half of domestically produced turf. Final energy demand (which excludes fuel employed in producing other fuel) amounted to some 8 million TOE, as losses occur in fuel transformation. Energy requirements in the household sector, defined as energy used in the home for power, light and heat, constituted some 28 per cent of this.

It could be argued that a component from the transport sector, that corresponding to energy used on non-business motoring and travel, should be counted as part of household energy. The component is very substantial and would nearly double household energy consumption in 1994-95. In addition, Conniffe *et al.* (1997) have forecast that private motoring energy consumption will, on its own, become larger than any other sector, because the stock of cars is expected to rise to over 1.6 million by 2010. It is also true that the Household Budget Survey does contain much information about car ownership, expenditures on the vehicles and also on motor fuels. However, it is probably better to investigate private motoring in a wider context, because there are interactions between private and business motoring and between private and public transport. In addition, the economic prosperity of recent years has led to a huge increase in new car registrations and the 1994-95 HBS is probably more out of date in regard to the stock and vintage of motor cars than it is for any other commodity. A study of transport related energy use would need to also employ data from other sources (excise records for motor fuels, etc.) that may well be less detailed, but more up to date. So this study will be confined to energy used for household power, light and heat.

There have been analyses of past rounds of the Household Budget Survey that have reported the relationship of energy consumption, and of its component fuels, to household income and household size. The authors included Leser (1964), who worked on data from the 1951-52 HBS; Pratschke (1969), who used the 1965-66 HBS; and Murphy (1975-76), who employed the 1973 survey. However, the HBS records expenditures on a comprehensive range of household commodities and these studies were concerned with the general breakdown of household expenditure on all goods and services and were not particularly interested in energy more than any other commodity. Also the authors (apart from the last named, who was an employee of the CSO) did not have access to household level data, but had to work at a much more aggregated level, using either published CSO tables, or specially provided compilations. So their investigations of energy expenditures and the interrelationships with characteristics of the households were much less detailed than is now feasible. Conniffe and Scott (1990) made some use of the 1980 and 1987 surveys, but again did not have access to household level data and chose to base their main analyses and conclusions on national aggregate time series data. Many of the analyses that will be described in this publication would not have been possible in the past.

The Household Budget Survey had a sample size of nearly eight thousand participating households and, as already mentioned, it records expenditures on a comprehensive range of household commodities and services. It also records the economic, educational, social and demographic characteristics of the households themselves, as well as possessions of household durables and appliances, powered by electricity or other fuel. Characteristics of the dwellings are also available in terms of age, size, structural type, possession of a gas connection, etc. So household energy expenditure can be related to a wide range of factors, besides those characteristics, such as family size and income, that are obviously very relevant. Most of the analyses that are reported in the subsequent chapters of this report are only based on the 1994-95 Household Budget Survey, but some use is made of data from the 1987 survey for comparative purposes.

Energy expenditure can itself be broken down into expenditure on the six component fuels: Piped Gas, Electricity, Coal, Turf, Oil and Liquefied Petroleum Gas. There are other minor components of household energy expenditures, such as candles, firelighters and kindling, but they are virtually negligible in overall expenditure terms. When looking at the mix of individual fuels within households, the availability of information at individual household level is essential for informative analyses. For example, investigating expenditure on gas in households has to take account of access to gas main connection, which can depend on the age, location and type of construction of the dwelling. Again, relative expenditures on fuels will depend on possessions of appliances utilising them and, in particular, on the type of central heating, if any, installed in the dwelling.

It may be worth mentioning that the 1994-95 Household Budget Survey also tried to record quantities of fuels in physical measures such as kilograms (for coal), litres (for oil) and units for electricity. But these are difficult to make use of and can even be misleading, because compositions may not be homogenous. For example, coal includes smokeless coal, smoky coal, and slack and these have different calorific values and prices. An aggregation, using prices as weights, to expenditure on coal makes more sense than an aggregation by weight. It is also awkward to compare consumptions of rival fuels in terms of kilograms v litres, or units v bales, and a common unit of measurement is needed. Again, considering overall household energy consumption requires such a common unit to permit aggregation over fuels. Finally, in the HBS the recorded expenditures are usually more reliable than are recorded quantities and, at the data processing stage, the Central Statistics Office sometimes replace the latter by imputed quantities obtained by dividing expenditure by price. For these reasons, the authors cited earlier investigated energy consumption in expenditure terms and this study will do likewise.

## 1.3 Income Elasticities of Fuels and Overall Household Energy

In studies of commodity demand, one very frequently calculated summary statistic is the *income elasticity* of expenditure on the commodity. This is defined as the percentage increase in commodity expenditure given a one per cent increase in income. It is obviously a very useful statistic in the case of energy, because it can be used to deduce the implications for energy consumption of various income projections or forecasts. When obtained for each fuel, the set of elasticities can suggest how the mix of fuels making up household energy may evolve with income change. Indeed, the main content of the references cited in the previous section consisted in the estimation of income elasticities from the various rounds of the Household Budget Survey using the aggregated data available. As already mentioned, fuel quantities will not be employed, but it is worth noting that the income elasticity of quantity consumed is identical to that of expenditure in the absence of price variation.

Elasticities could conceivably vary with the type of household and examining the extent of these variations could permit more refined forecasts or even reveal biases in the aggregated estimates. In the past the unavailability of household level data limited the extent to which this could be investigated and attention was usually restricted to taking some account of the number of people in the households. With the data currently available, much more investigation is possible. In particular, the possibly distorting effects on elasticity estimation of the fuel allowances available to certain types of households can be taken into account.

Perhaps at this point a substantial limitation of the 1994-95 HBS data should be admitted. Because the survey was conducted over a relatively short time period (July 1994 to June 1995) and because Ireland is a small country, there is very little variation in fuel prices. Energy demand is affected by price and the relative prices of fuels can, at least in the long term, affect the fuel mix greatly. So it would be interesting to derive price elasticities as well as income elasticities, but this cannot be done from the 1994-95 data. Adding in the data from past surveys might seem to offer a solution, but there is the problem of lack of household level data and also the fact that, with seven year gaps, structural changes in the household sector would be confounded with price changes.

## 1.4 Topics of Later Chapters

Chapter 2 discusses the volume and composition of expenditure on household energy in 1994-95 and the changes that had occurred since 1987 in overall energy consumption and in the fuel mix. Explanations are sought through the effects of some major determining factors, such as income, location, possession of central heating and the legal restrictions on certain fuels in urban areas. The importance of the availability of gas connection and type of central heating on the composition of the fuel mix will become apparent. So Chapter 3 examines gas connection in terms of location, family composition, social group of household, type of building and year of construction. Possession of central heating is also analysed in the light of these characteristics. Further analyses look at the frequencies of the variously fuelled central heating systems, how these are affected by the household characteristics and the implications for energy expenditure. There is also a brief comparison with corresponding data for Northern Ireland as revealed in a 1996 survey.

Chapter 4 turns to the quantification of the relationship between aggregate household energy expenditure and income and describes the issues involved. In particular, the appropriate definition of income is discussed, along with the corresponding implications for the method of analysis. The income elasticity of energy expenditure is estimated, first for the State as a whole and then for urban and rural households. The effect of the number of people in the household is investigated by estimating separate income and household size coefficients and making the appropriate energy adjustments to elasticities. Anomalies in some findings emphasise the need for clarification through estimation of elasticities at individual fuel level and the next three chapters undertake this.

Chapter 5 considers electricity expenditure. Measurement of the effects of income and other factors on electricity demand are complicated by the existence of free electricity allowances. Over 18 per cent of the survey households, mainly with pensioners as heads of household, possessed the allowance. Quite considerable distortions in estimates result from ignoring the existence of the allowance. Deriving the appropriate adjustments to correct these is quite complicated, requiring examination of allowance holding households in terms of location, income and composition, and analysis of their economic behaviour. The presentation in the Chapter is simplified by referring much of the technical detail to a more specialised journal paper by the author (Conniffe, 2000). However, the overall effects of the free electricity scheme are summarised and corrected estimates of elasticities are obtained and interpreted.

The two fuels with the highest income elasticities – Gas and Oil – are examined in Chapter 6. Because demand for both these fuels is largely driven by demand for central heating, the findings relate back to the material in Chapter 3 on possession of central heating. The possibility of saturation of the demand for central heating would have strong implications for these fuels and could greatly alter patterns. Chapter 7 proceeds to consideration of the "inferior" fuels – Coal, Turf and LPG – where the survey data show consumption falling, rather than rising, with increasing income. The explanations for the observed patterns are discussed and illustrated by relevant analyses. Chapter 8 draws together the information on elasticities obtained in the three previous chapters and compares these 1994/95 estimates with previously published figures based on earlier rounds of the Household Budget Survey.

The ESRI's Policy Research Series is, as the title indicates, usually intended for publications containing conclusions directly relevant to policy issues. The focus of this paper is largely on eliciting whatever information the Household Budget Survey can provide about key parameters and relationships in the household energy sector and so providing some building blocks for future policy analysis. However, Chapter 9, having summarised the conclusions that can be drawn from all the analyses, does consider some implications for various aspects of energy policy.

# 2. Household Energy Expenditures

## 2.1 Patterns of Expenditures on Fuels in 1994/95

Household energy is understood to mean energy used in the home for power, light and heat and in the vast majority of households comprises more than one fuel, so that household energy expenditure is totalled over fuel expenditures. The fuels considered are Piped Gas (subsequently just called Gas); Electricity, Coal (aggregated over anthracite, coal and slack); Turf (aggregated over briquettes and loose turf); Oil and LPG (Liquefied Petroleum Gas). These six fuels account for almost all household energy expenditure. Table 2.1 shows average household expenditures from the 1994-95 survey for these fuels for the State as a whole, and for urban and rural areas. The table also shows average overall energy expenditures, total household expenditures (the former being 4.8 per cent of the latter for the State) over all categories of expenditure and average household size.

**Table 2.1: Household Budget Survey, 1994-95, Summary of Household Energy Expenditures**

| | Whole of State | Urban | Rural |
|---|---|---|---|
| Number of households in survey | 7,877 | 5,066 | 2,811 |
| Average household expenditure £/week | 311.80 | 328.30 | 283.50 |
| Average energy expenditure £/week | 14.99 | 14.43 | 15.95 |
| Gas expenditure £/week | 1.38 | 2.17 | .02 |
| Electricity expenditure £/week | 6.16 | 6.30 | 5.94 |
| Coal expenditure £/week | 2.75 | 2.64 | 2.95 |
| Turf expenditure £/week | 1.70 | .82 | 3.19 |
| Oil expenditure £/week | 2.14 | 1.90 | 2.55 |
| LPG expenditure £/week | .86 | .60 | 1.30 |
| Average household size persons | 3.28 | 3.21 | 3.39 |

*Note:* Average energy household expenditure is taken as the sum of expenditures on gas, electricity, coal, turf, oil and LPG. There are other household energy expenditures recorded in the HBS Fuel and Light category (firewood, firelighters etc.), but these are small. Motoring fuels are recorded under the separate Transport category.

Average household expenditure can be taken as a proxy for income and was lowest for rural households, although their energy expenditures were somewhat higher. The negligible expenditure on piped gas in rural households is, of course, a reflection of lack of access to pipelines and the relatively high rural expenditure on turf includes the value of on-farm production. The lower expenditure on electricity in rural areas is worth noting and will be returned to in later chapters.

## 2.2 Comparison with 1987

It is interesting to compare these 1994-95 results with the corresponding data from the 1987 survey. Because of inflation it can be misleading to compare the expenditures directly. Instead, the 1987 fuel expenditures were first scaled up to 1994 prices by applying the increase in the Consumer Price Index (CPI) for energy, which was 6 per cent, and scaling up total household expenditure by the increase in the overall CPI, which was 21 per cent. (The fact that the overall CPI was so much higher implies real energy prices fell substantially between the surveys.) The resulting real percentage increases in fuel expenditures, overall energy expenditure and total household expenditures are shown in Table 2.2.

**Table 2.2: Real Expenditure Increases (%) 1987 to 1994**

| | Whole of State | Urban | Rural |
|---|---|---|---|
| Average household expenditure | 15.5 | 16.3 | 13.9 |
| Average energy expenditure | 5.3 | 1.1 | 12.0 |
| Gas expenditure | 97.1 | 94.8 | Not applicable |
| Electricity expenditure | 13.2 | 3.2 | 28.8 |
| Coal expenditure | -30.9 | -38.9 | -14.0 |
| Turf expenditure | -11.9 | -4.6 | -15.2 |
| Oil expenditure | 110.0 | 86.5 | 153.0 |
| LPG expenditure | -19.8 | -30.2 | -9.1 |

The increase in real average household expenditure of 15.5 per cent reflects the increase in living standards between 1987 and 1994. The increase in average overall energy expenditure is much lower at 5.3 per cent and is quite compatible with the conventional wisdom that demand for energy is income inelastic – that is, the proportion of income expended on energy falls as incomes rise. However, the details of the table show substantial variation between urban and rural households and dramatic changes to the relative expenditures on fuels. The percentage increase in energy expenditure is much higher for rural households and little below their total household expenditure (or income) increase. As regards fuels, expenditures on gas and oil increased greatly, expenditure on electricity rose substantially, while spending on coal, turf and LPG decreased considerably, especially in the case of coal.

There were so few rural households connected to piped gas in either 1987 or 1994 that calculation of an increase would be meaningless. The somewhat higher percentage increase shown for gas for the "State" than for "Urban" households just results from the increased proportion of urban households in 1994. The decrease in expenditure on coal no doubt reflects some preference for cleaner and more convenient fuels, but the far greater decrease for urban than for rural areas shows the impact of the legal restrictions on the use of smoky coal in cities that were introduced in 1990. Householders facing the higher price for smokeless coal (and the cost and inconvenience of modifying fire-grates to burn it) may well have decided to move to another fuel altogether. The percentage decrease in turf expenditure was actually lower in urban than in rural areas. While it is true that the urban percentage change was from a far smaller base than the rural one, it would have been greater had not turf briquettes been granted exemption from legislative restriction.

The largest percentage increase was for oil in rural households, followed by gas and oil in urban households. These increases are so much greater than the household income changes that demand for these fuels seems surprisingly income elastic. The explanation is that demand for both of these fuels is a derived demand, with the prevalence of central heating the determining factor. The proportion of houses with some form of central heating has been rising steadily for many years and Table 2.3 compares the findings of the 1987 HBS with the 1994-95 HBS in this regard.

**Table 2.3: Percentages of Households with Full⁺ Central Heating**

| Type of Central Heating | State 1987 | State 1994 | Urban 1987 | Urban 1994 | Rural 1987 | Rural 1994 |
|---|---|---|---|---|---|---|
| Electric | 0.8 | 2.2 | 1.1 | 3.1 | 0.4 | 0.6 |
| Gas | 3.5 | 14.2 | 5.4 | 21.1 | 0.4* | 1.8* |
| Oil | 12.2 | 25.4 | 13.3 | 24.6 | 10.4 | 27.0 |
| Solid Fuel | 30.8 | 20.7 | 28.8 | 16.1 | 34.2 | 29.0 |
| Dual System | 4.2 | 5.9 | 4.4 | 3.9 | 3.9 | 9.5 |
| TOTAL | 51.5 | 68.4 | 53.0 | 68.8 | 49.3 | 67.9 |

*In this table the classification "Gas" for central heating in rural areas includes non-piped gas (LPG).

+ In 1994 partial central heating was installed in 4.7 per cent, 4 per cent and 6 per cent of State, Urban and Rural households. Some tables in Chapter 3 will include information on partial systems.

Overall the proportion of dwellings with full central heating increased from just over half in 1987 to over two-thirds in 1994. The increase was greatest for rural areas, where the proportion of centrally heated homes had lagged below that for urban areas in 1987, but almost caught up by 1994. The increase in rural areas was predominantly by installation of oil fuelled systems. In urban areas new installations (or conversions) were most frequently of gas systems, although oil systems also increased substantially. Solid fuel central heating declined in both urban and rural areas, though by a much larger amount in urban areas, probably because of the factors already mentioned in relation to the decline in coal consumption.

The data in Table 2.3 clearly help explain the patterns in Table 2.2 and the substitution between fuels from 1987 to 1994. Demand for centrally heated housing and the system options available may largely determine demands for fuels other than electricity. The demand for electricity is also a derived demand, of course, largely determined by the stock of electric powered appliances possessed by the household. But there is no substitute fuel for electricity in most applications. The contrast between urban and rural areas as regards increasing elasticity demand is noticeable. The urban electricity expenditure increase is about one-fifth of the household expenditure increase (implying a low income elasticity), while for rural areas it is twice it (implying a higher income elasticity).

The household budget surveys record possession of household electric appliances and changes in the stocks of appliances should help explain differences in electricity consumption between surveys and between groups within a survey. An index of household electrical appliance possession (owned or rented) was based on the ten items: vacuum cleaner, clothes dryer, washing machine, dishwasher, refrigerator with freezer, separate deep freeze, microwave oven, video recorder, stereo and home computer. The calculation was simple for each household – just sum the number of appliances possessed and express as a percentage of ten. Various appliances were not included (television set, for example) because for many years hardly any household has been without them and so they cannot explain variations between or within recent surveys. Table 2.4 shows how average values of the index varied from urban to rural areas in 1987 and 1994.

**Table 2.4: Index of Possession (Max.=100) of Electrical Appliances 1987 and 1994**

| Year | Average for State | Average for Urban | Average for Rural |
|---|---|---|---|
| 1987 | 30.4 | 33.2 | 25.4 |
| 1994 | 47.0 | 48.6 | 43.7 |

The increase in the index was greater for the rural than for the urban areas, indicating the same "catching up" process as in the case of central heating and helping explain the greater increase in rural electricity consumption seen in Table 2.2. However, the urban versus rural comparison of energy expenditures in Table 2.1 has still not been adequately explained. In spite of "catching up", possession of central heating and electrical appliances in rural areas is still below urban levels and yet 1994 rural energy expenditure is higher. Table 2.1 showed rural electricity expenditures were lower, so the explanation must lie with other fuels. That table also showed the average oil bill to be substantially higher for rural rather than urban households. It is tempting to see the non-availability of gas in rural areas as a major factor, since oil and gas compete as urban central heating fuels, but it will be shown in the next chapter that this is not the case, or at least not directly. The survey's conventions for pricing home farm produced and consumed turf might possibly have some role, although farms comprise only 25 per cent of the survey's rural households. The possible influence of differences in the characteristics of the rural housing stock will be examined in the next chapter. That special features associated with rural rather than urban living are responsible is supported by the fact that the 1987 Household Budget Survey showed urban and rural energy expenditures almost equal, before the "catching up" in possessions process, already described had occurred.

It is interesting to relate the patterns in Table 2.2 to the estimates for energy growth and elasticities made in Conniffe *et al.* (1997). To assess the compatibility of high Irish economic growth with the proposed Kyoto targets for Irish greenhouse gas emissions, forecasts were required of future energy demand assuming the continuance of current trends. Annual data series were available for the various fuels but, except for transport related demand, only aggregated over the household, commercial and industrial sectors. Time series analysis found that in recent years overall energy was inelastically related to income (that is, energy consumption was increasing more slowly than GDP), but that patterns differed greatly between fuels. Coal and turf were decreasing, oil and LPG were relatively constant, while electricity and gas were increasing, the former at just a slighter lower rate than GDP and the latter much more rapidly than it.

Although Table 2.2 involves comparisons at just two points in time and for the household sector only, it does support most points in the aggregate analysis. Coal and turf decline, while electricity and gas increase, the former somewhat more slowly than total household expenditure, the latter much more rapidly. The main contrast is the oil increase by households, which would imply a balancing drop in the commercial or industrial sectors to maintain constancy. As already seen, the oil increase by households is a rural phenomenon, related to growth in possession of central heating.

As regards the general issue of forecasting the volume and composition of future energy demand by the household sector, estimates of future population and new household formation are obviously important. But the geographical locations of new housing will matter too and will interact with restrictions on availability of fuels, which may exist for either infrastructural or legislative reasons. An approach to saturation of the market for central heating could dramatically reduce forecast demand for oil and gas. For existing households and in spite of the increase since 1987, Table 2.3 shows the 1994-95 level of possession of central heating is still short of saturation at under 70 per cent. Clearly, more frequent measures of central heating possession than those provided by rounds of the Household Budget Survey are desirable for forecasting. In the case of the index of electrical appliances in Table 2.4 it is true that some items are near saturation (91 per cent of urban households possessed a vacuum cleaner in 1994), but others could grow greatly (6 per cent of households in the State had a home computer in 1987 and 16 per cent in 1994). Also, new appliances, requiring electrical power, are regularly invented, although much could depend on how power intensive they are.

## 2.3 Gas Connected Households

A comparison of the 1987 survey with the 1994-95 survey for the sub-sector of gas connected urban households is specially interesting in view of the expanding gas share of the energy market. Table 2.5 makes the comparison, with 1987 expenditures recalculated at 1994 prices to offset inflation.

**Table 2.5: Energy Expenditures in Gas-connected Households (1994 prices)**

| | 1987 | 1994-95 | % Change |
|---|---|---|---|
| Number of gas-connected households | 1,063 | 1,334 | 25.5 |
| Average household expenditure £/week | 267.6 | 367.0 | 37.1 |
| Average energy expenditure £/week | 14.82 | 15.32 | 1.0 |
| Gas expenditure £/week | 5.04 | 7.99 | 58.5 |
| Electricity expenditure £/week | 5.38 | 5.83 | 8.4 |
| Coal expenditure £/week | 3.30 | .80 | -75.8 |
| Turf expenditure £/week | .23 | .18 | -21.7 |
| Oil expenditure £/week | .32 | .31 | -3.1 |
| LPG expenditure £/week | .55 | .19 | -65.4 |

Comparison with Table 2.1 shows that gas connected households in the 1994 survey were the highest average income (as indicated by total household expenditure) category. In 1987 average incomes of gas-connected households were below the urban average, so new connections made between the survey dates must have been proportionately greater among the higher income groups. One would expect higher income groups to consume more energy, so it is noteworthy by how little overall energy expenditure increased between the survey years. The greatest change in the fuel mix between surveys was the large drop in coal consumption and in 1987 there may still have been many households using gas for cooking, but coal for heating, which was once common in Dublin's inner city and older suburbs.

# 3. Gas Connection, Central Heating and Household Characteristics

The previous chapter has shown how important the factors of gas connection and type of central heating possessed are in determining change between survey years and the fuel mix within a survey year. So this chapter gives closer attention to relevant survey information about these factors.

## 3.1 Gas Connection and Household Characteristics

Commencing with household location, the frequency of gas connection is obviously virtually zero for rural areas, so the regional distribution will reflect the proportions of urban and rural housing within regions. Table 3.1 shows the frequencies and percentages for the 8 regions.

**Table 3.1: Gas Connection by Region – Percentage of Households**

| Region | Border | Dublin | Mideast | Midland | Midwest | S'east | S'west | West |
|---|---|---|---|---|---|---|---|---|
| No Gas | 100 | 55 | 97 | 100 | 92 | 97 | 84 | 100 |
| Gas | 0 | 45 | 3 | 0 | 8 | 3 | 16 | 0 |
| Number | 1,003 | 2,353 | 630 | 418 | 622 | 971 | 1,131 | 749 |

Clearly Dublin and the South-West regions account for the bulk of gas connections. A more interesting breakdown is by type of building within urban areas and this is presented in Table 3.2.

**Table 3.2: Gas Connection by Building Type within Urban Areas – Percentage of Households**

| Type | Bed-sit | APARTMENTS | | | Detached House | Semi-D & Terraced | Other |
|---|---|---|---|---|---|---|---|
| | | Converted | Large Block | Small Block | | | |
| No Gas | 92 | 87 | 80 | 79 | 85 | 68 | 74 |
| Gas | 8 | 13 | 20 | 21 | 15 | 32 | 26 |
| Number | 77 | 209 | 224 | 59 | 1,029 | 3,439 | 31 |

The numbers of building types occurring in the survey of course reflect their frequencies in the national housing stock. It is interesting that the proportion of gas connected apartments in the survey is virtually the same whether these are in large apartment blocks or small blocks. Apartments do have a lower proportion of gas connection than semi-detached or terraced housing. The lower frequency of gas connection for detached, rather than semi-detached or terraced houses, may imply that even in urban areas some estates of detached houses may not have had access to a main, at least in 1994/95. Houses built before the advent of natural gas may have been less likely to have had such access. Table 3.3 examines gas connection by year of building construction.

**Table 3.3: Gas Connection by Year of Construction (Urban Areas) – Percentage of Households**

| Year | <1918 | 1918-45 | 1946-60 | 1961-70 | 1971-80 | 1981-85 | >1986 |
|---|---|---|---|---|---|---|---|
| No Gas | 77 | 63 | 63 | 66 | 84 | 85 | 76 |
| Gas | 23 | 37 | 37 | 34 | 16 | 15 | 24 |
| Number | 731 | 836 | 673 | 679 | 1,105 | 578 | 457 |

The relationship of gas connection to age of house is U shaped. For houses built before 1970, the proportion gas connected exceeded a third. This more than halves for houses constructed between 1971 and 1985, but increases again for construction dates after 1986. Given that all houses in the survey were built no later than 1994, this increase probably understates the scale of the gas industry revival.

The relationship between household composition and gas connection is investigated in Table 3.4.

**Table 3.4: Gas Connection by Family Composition (Urban Areas) – Percentage of Households**

| Comp-osition | A | 2A | 2A+C | 2A+2C | 2A+3C | 2A+kC | 3A | 3AwC | 4A | 4AwC | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|
| No Gas | 76 | 72 | 75 | 71 | 75 | 80 | 66 | 72 | 54 | 72 | 81 |
| Gas | 24 | 28 | 25 | 29 | 25 | 20 | 34 | 28 | 46 | 28 | 19 |
| No. | 1193 | 952 | 396 | 592 | 410 | 281 | 227 | 296 | 76 | 130 | 472 |

*Note:* A=Adult C=Child k=>3 w=with at least one

In interpreting the table it needs to be remembered that any family member aged 16 or over is counted as adult. So the family compositions with the highest proportions of gas connection – 3 and 4 adult households – largely consist of a married couple and one or two children in their late teens or early twenties. These family compositions are less likely to be associated with apartment dwellings than with suburban semi-detached houses, so reconciling the pattern with that of Table 3.2. The higher average age of head of household (relative to households with young children) will also tend to be associated with higher income, so that there may be an income effect also.

In keeping with this theme, Table 3.5 breaks gas connection down by Social Group.

**Table 3.5: Gas Connection by Social Group (Urban Areas) – Percentage of Households**

| SG | HP | LP | SE | SAL | INM | ONM | SM | SSM | USM | UK |
|---|---|---|---|---|---|---|---|---|---|---|
| No Gas | 66 | 70 | 65 | 68 | 70 | 73 | 76 | 69 | 80 | 82 |
| Gas | 34 | 30 | 35 | 32 | 30 | 27 | 24 | 31 | 20 | 18 |
| No. | 278 | 394 | 401 | 137 | 726 | 715 | 812 | 255 | 288 | 944 |

Here HP and LP stand for higher and lower professional groups, SE and SAL for self-employed and salaried, INM and ONM for intermediate non-manual and other non-manual workers, SM and SSM for skilled and semi-skilled manual, USM stands for unskilled manual and UK for unknown. While gas connection is substantial for all Groups, there is a definite tendency for somewhat larger frequencies of connection for the higher Social Groups. Of course, the Farmer Social Group is not represented since only urban households have been considered.

## 3.2 Central Heating and Gas Connection

This section and the next investigates factors affecting possession of central heating and the choice of fuel. Partial central heating systems, mentioned in the footnote to Table 2.3, can sometimes be quite substantial, especially in rural dwellings, and are then included. Table 3.6 looks at how frequency of central heating is related to gas connection.

**Table 3.6: Central Heating by Gas Connection – Percentage of Households**

| | No Gas Connection | Gas Connection | All Households |
|---|---|---|---|
| No central heating | 32 | 16 | 29 |
| Central heating | 68 | 84 | 71 |
| Numbers | 6,543 | 1,334 | 7,877 |

Clearly, possession of central heating is substantially higher in gas connected houses. For houses with central heating, Table 3.7 extends the analysis to examine the frequencies of the various central heating systems. The "Back boiler" and most of the "Other" (largely combination cooking/house heating systems, but also including a few systems that are difficult to categorise) use solid fuel. Separate solid fuel systems are relatively rare.

**Table 3.7: Percentages of Types of Central Heating System**

| | No Gas Connection | Gas Connection | All Households |
|---|---|---|---|
| Oil | 50 | 4 | 41 |
| Back boiler | 20 | 3 | 16 |
| Piped gas | 0 | 91 | 18 |
| LPG | 2 | 1 | 2 |
| Solid fuel | 2 | 0 | 2 |
| Electricity | 5 | 1 | 4 |
| Dual | 1 | 0 | 1 |
| Other | 20 | 0 | 16 |

As would be expected, gas central heating is greatly predominant in gas connected houses. The combination of the 84 per cent figure from Table 3.6 and the 91 per cent figure from this table shows the extent to which household demand for gas is a demand for central heating. Oil fired systems are the most frequent type of central heating in houses without gas connection. Clearly, any prediction of future shares of the central heating market between gas and oil would depend critically on the assumed location of housing and accessibility to the gas grid. The classification of central heating systems by urban or rural location, shown in Table 3.8, may further emphasise the point.

**Table 3.8: Percentages of Types of Central Heating System by Urban/Rural Location**

| | Urban | Rural |
|---|---|---|
| Oil | 38 | 47 |
| Back boiler | 17 | 13 |
| Piped gas | 29 | 0 |
| LPG | 2 | 2 |
| Solid fuel | 1 | 3 |
| Electricity | 5 | 2 |
| Dual | 1 | 1 |
| Other | 7 | 32 |

In urban areas oil and gas compete, although as the previous tables have shown, the competition is largely prior to gas connection. In rural areas oil is unchallenged, except by the "other" category.

## 3.3 Central Heating and Household Characteristics

Turning to how possession of central heating relates to various household characteristics, Table 3.9 gives a breakdown by building type.

Note that numbers, especially for detached houses, are larger than in Table 3.2, because here the whole country is included, rather than urban areas only. Central heating is most frequent in detached and semi-detached houses and least so in bed-sits and the "other" category. For housing with central heating, Table 3.10 details the types of systems.

**Table 3.9: Central Heating by Building Type – Percentage of Households**

| Type | Bed-sit | Apart. Converted | Apart. Lr. Block | Apart. Sl. Block | Detached House | Semi-D & Terraced | Other |
|---|---|---|---|---|---|---|---|
| No CH | 74 | 62 | 50 | 63 | 23 | 28 | 84 |
| CH | 26 | 38 | 50 | 27 | 77 | 72 | 16 |
| Number | 77 | 213 | 224 | 59 | 3,617 | 3,620 | 67 |

**Table 3.10: Types of Central Heating by Building Type – Percentage of Households**

| Type | Bed-sit | Apart. Converted | Apart. Lr. Block | Apart. Sl. Block | Detached House | Semi-D & Terraced | Other |
|---|---|---|---|---|---|---|---|
| Oil | 65 | 41 | 37 | 9 | 51 | 31 | 27 |
| Back b. | 0 | 6 | 3 | 14 | 12 | 22 | 27 |
| Gas | 20 | 22 | 27 | 23 | 4 | 33 | 9 |
| LPG | 0 | 1 | 0 | 0 | 3 | 1 | 19 |
| Solid f. | 0 | 1 | 0 | 4 | 2 | 1 | 9 |
| Electric | 15 | 25 | 33 | 50 | 2 | 4 | 9 |
| Dual | 0 | 0 | 0 | 0 | 1 | 1 | 0 |
| Other | 0 | 4 | 0 | 0 | 25 | 7 | 0 |

It should be remembered here that working only with households with central heating removes the differences between different household types in overall possession level, even if it clarifies relationships between the different heating systems and household type. Oil fuelled systems are most common except in small apartment blocks, where electricity is more frequent, and in semi-detached houses, where gas is. Of course, the dominance of oil for detached houses is not surprising given that rural areas are included. Electricity seems to be a competitor only in an apartment setting.

Table 3.11 looks at possession of central heating by year of house construction.

**Table 3.11: Central Heating by Year of Construction – Percentage of Households**

| Year | <1918 | 1918-45 | 1946-60 | 1961-70 | 1971-80 | 1981-85 | >1986 |
|---|---|---|---|---|---|---|---|
| No CH | 49 | 42 | 31 | 18 | 20 | 21 | 8 |
| CH | 51 | 58 | 69 | 82 | 80 | 79 | 92 |
| Number | 1,463 | 1,221 | 946 | 897 | 1,645 | 961 | 740 |

Numbers again exceed those of Table 3.3 because rural areas are included. Old houses have relatively lower proportions of central heating, while about 80 per cent of dwellings dating from 1960 to 1984 have it. Since 1986, few dwellings have been constructed without it.

Type of central heating may possibly be influenced by family composition. Table 3.12 examines this.

**Table 3.12: Type of Central Heating by Family Composition (Urban Areas) of Households**

| Com. | A | 2A | 2A+C | 2A+2C | 2A+3C | 2A+kC | 3A | 3AwC | 4A | 4AwC | Other |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil | 38 | 43 | 46 | 46 | 44 | 37 | 41 | 40 | 31 | 35 | 37 |
| Back b. | 15 | 14 | 17 | 17 | 17 | 20 | 13 | 17 | 13 | 18 | 20 |
| Gas | 20 | 19 | 18 | 17 | 16 | 12 | 19 | 17 | 26 | 17 | 21 |
| LPG | 2 | 2 | 2 | 2 | 1 | 2 | 1 | 1 | 3 | 1 | 1 |
| Solid fuel | 2 | 2 | 1 | 1 | 2 | 3 | 2 | 2 | 1 | 2 | 1 |
| Elect. | 9 | 5 | 4 | 4 | 1 | 1 | 2 | 1 | 5 | 2 | 9 |
| Dual | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 2 | 1 | 1 |
| Other | 13 | 14 | 12 | 12 | 18 | 24 | 21 | 21 | 19 | 24 | 10 |

*Note:* A=Adult C=Child k=>3 w=with at least one

Again, the table is based on houses with central heating, removing differences due to different overall possession rates between household types. The remaining distributions are rather similar for all household compositions, but families with more than three young children are below average as regards possession of a gas heating system, while households consisting of four adults – probably usually a married couple with late teen or grownup children – have the highest frequency of gas heating. This correlates with the incidences of gas connection for these household types as shown earlier in Table 3.4. Possession of central heating is classified by social group in Table 3.13.

**Table 3.13: Central Heating by Social Group – Percentage of Households**

| SG | HP | LP | SE | SAL | INM | ONM | SM | SSM | USM | UK | FM | OA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No CH | 7 | 12 | 8 | 8 | 20 | 30 | 22 | 35 | 46 | 50 | 31 | 49 |
| CH | 93 | 88 | 92 | 92 | 80 | 70 | 78 | 65 | 54 | 50 | 69 | 51 |
| Number | 354 | 518 | 499 | 166 | 886 | 976 | 1,237 | 335 | 453 | 1,310 | 911 | 232 |

The social groups are the same as in Table 3.5, except that farmers (FM) and other agricultural workers and fishermen (OA) have been added. There is obviously a definite relationship between central heating and social group, with over 90 per cent possession in higher social group households, falling to near 50 per cent for unskilled manual, other agricultural and unknown.

Finally, a classification of type of heating by social group is given in Table 3.14.

**Table 3.14: Type of Central Heating by Social Group – Percentage of Households**

| SG | HP | LP | SE | SAL | INM | ONM | SM | SSM | USM | UK | FM | OA |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Oil | 53 | 50 | 53 | 50 | 44 | 36 | 38 | 26 | 25 | 36 | 43 | 32 |
| Ba. b. | 6 | 8 | 6 | 8 | 16 | 20 | 20 | 28 | 27 | 21 | 10 | 31 |
| Gas | 26 | 23 | 28 | 27 | 23 | 21 | 17 | 24 | 16 | 17 | 0 | 2 |
| LPG | 3 | 3 | 2 | 1 | 2 | 2 | 2 | 2 | 0 | 1 | 2 | 2 |
| Sol. f. | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 4 | 2 | 2 | 1 |
| Elect. | 5 | 7 | 4 | 5 | 5 | 3 | 3 | 2 | 1 | 7 | 2 | 2 |
| Dual | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 1 |
| Other | 5 | 7 | 5 | 7 | 8 | 15 | 17 | 16 | 27 | 16 | 40 | 29 |

Here there are clear differences in patterns across social groups. Higher social groups favour oil or gas – the clean, convenient, fuels. With lower social class, the frequencies of these systems falls and backboiler, solid fuel and "other" systems become more common. This effect, taken in conjunction with the possession effect demonstrated in Table 3.13, shows the importance of social class – and hence income – on demand for oil and gas relative to other fuels.

## 3.4 Gas Expenditure versus Oil Expenditure and Urban versus Rural Energy Expenditures

In Chapter 2 the possibility was raised that lack of availability of piped gas might be a factor in the higher average energy expenditure of rural households. Rural oil expenditure was substantially higher and household use of oil is virtually entirely as a central heating fuel. Comparing the relative prices of fuels is not a straightforward matter because the relative utilisable energy contents have to be allowed for. Using the Forbairt (1994) figures on calorific values and "delivered cost" does indicate that oil and gas prices are similar. However, the engineering approach which compares the cost of carrying out a specified end use task, taking into account technical efficiencies and tariffs, has often been criticised on the grounds that it takes little account of actual household circumstances. It has been argued that truly representative fuel costs or "prices"' should be based on household survey data, averaged over the differing vintages and efficiencies of equipment and the varying environments in which they operate.

Some quite elaborate analyses have been conducted (for example: Bartels, Fiebig and Plumb, 1996), but a fairly simple calculation will suffice here.

Dividing average expenditure on urban oil, £1.90 (from Table 2.1), by the proportion of urban households with oil fired central heating, 0.25 (from Table 2.3), gives a weekly average expenditure on oil central heating of £7.60. The earlier tables in this chapter have demonstrated that household use of gas is also predominantly for central heating, so the corresponding figure for gas is £7.99 (from Table 2.5). These are close enough to support the earlier oil and gas equivalence in terms of "useful heat" and certainly does not suggest that unavailability of gas is a factor in the urban – rural expenditure difference. But it could perhaps be argued that lack of competition with gas in rural areas permits higher oil prices. Taking rural figures, the corresponding calculation gives £9.44 as weekly average expenditure on oil central heating. However, differences in type, age and size of dwellings could well be responsible. Table 3.15 classifies the survey dwellings by type for urban, rural non-farm and farm households.

**Table 3.15: Building Type by Urban and Rural (Farm and Non-farm) – Percentage of Households**

| Type | Bed-sit | Apart. Converted | Apart. Lr. Block | Apart. Sl. Block | Detached House | Semi-D & Terraced | Other |
|---|---|---|---|---|---|---|---|
| Urban | 1.5 | 4.1 | 4.4 | 1.1 | 20.1 | 68.2 | 0.6 |
| Rural NF | 0 | 0.2 | 0 | 0.1 | 89.6 | 8.5 | 1.6 |
| Rural F | 0 | 0 | 0 | 0.1 | 97.7 | 1.7 | 0.5 |

Here the percentages total to 100 along the rows. There are obviously huge differences in pattern, with detached houses dominating in rural areas and apartments virtually absent. Table 3.16 applies the same breakdown to age of dwelling.

**Table 3.16: Year of Construction by Urban and Rural (Farm and Non-farm) – Percentage of Households**

| Year | <1918 | 1918-45 | 1946-60 | 1961-70 | 1971-80 | 1981-85 | >1986 |
|---|---|---|---|---|---|---|---|
| Urban | 14.5 | 16.6 | 13.3 | 13.3 | 21.9 | 11.4 | 9.0 |
| Rural NF | 22.9 | 13.5 | 8.7 | 7.5 | 20.3 | 16.2 | 10.9 |
| Rural F | 32.6 | 14.1 | 12.0 | 9.4 | 16.4 | 7.5 | 8.0 |

There are many more old (pre 1918) houses in rural than in urban areas. This is particularly so for farm households, where almost a third of dwellings were constructed before 1918. The percentages of dwellings constructed before 1970 were 48, 53 and 68 for urban, rural non-farm and farm houses respectively. Tables 3.15 and 3.16, and particularly the former, strongly suggest that residual urban-rural differences are due to differences in the characteristics of the housing stock and not to fuel prices. There could also be a housing utilisation effect, if rural homes are more likely to be occupied during the day.

## 3.5 Comparisons with Northern Ireland

The Northern Ireland Housing Executive conduct the House Condition Survey at five year intervals, the most recent being that for 1996. The Housing Executive is also the Energy Conservation Authority for Northern Ireland. So, although the primary purpose of the survey is to monitor the condition of the housing stock, with emphasis on identifying houses in danger of becoming unfit for habitation, it also records details of heating systems, energy conservation measures, etc. The survey is actually larger and more intensive than the Republic's Household Budget Survey, or its UK equivalent – the Family Expenditure Survey. A sample of 10,000 dwellings are visited and householders interviewed, while the structural features are surveyed by experts.

The proportion of all houses with central heating in 1996 was 87 per cent, or 89 per cent if unoccupied houses were excluded, which was an increase of 6 per cent on the previous (1991) survey estimate. The percentage of all urban houses with central heating was 89 and the corresponding figure for rural dwellings was 83 per cent. These figures are all considerably higher than their equivalents for the Republic in 1994-95, which supports the view that the frequency of central heating here (at least in 1994) is well short of the saturation level. Some of the patterns noted in the tables of Section 3.2 also occur (allowing for the higher level of possession of central heating) in the Housing Executive (1998) report. Older dwellings and houses in rural locations were less likely to have central heating; higher income social groups were more likely to have it and as regards the effect of family composition – single adult households were least likely to possess it and households with multiple adult members were most likely to. There were some differences, for example, semi-detached houses were a little more likely to have central heating than detached houses.

As regards fuels, the pattern, evident in the comparison of the 1987 Household Budget Survey and the 1994-95 survey in Chapter 2, away from "dirty" solid fuels appears again in the House Condition Survey. The 1991 survey had shown 47 per cent of dwellings had coal based systems (39 per cent back boilers), but the figure had fallen to 31 per cent by 1996, while the percentage of dwellings with oil based systems had increased from 21 to 37. So oil based systems held a much greater share than in the Republic, reflecting the availability of natural gas in the Republic and its unavailability (in 1996) in Northern Ireland. The Housing Executive (1998) report shows clear awareness of the greenhouse gas issue and the desirability of replacing oil by natural gas. It comments specifically (pg. 117) that the volume of carbon dioxide emissions from the average Northern Ireland house is twice that from a British one and attributes the difference to the unavailability of natural gas. There are clearly implications for the Irish gas industry (given the recent gas field find off Mayo) in the existence of this potential market of 602 thousand dwellings, with 87 per cent already equipped with central heating.

# 4. THE HOUSEHOLD ENERGY EXPENDITURE AND INCOME RELATIONSHIP

### 4.1 Relating Household Energy Expenditure to "Income"

Working within the 1994-95 survey, the expenditures of households on fuels can be related to the weekly "incomes" (actually total weekly expenditures) of the households and to household sizes. It should not be assumed that the findings ought to fully match the patterns of Table 2.2 for changes in energy expenditures and incomes from 1987 to 1994. As was mentioned in Chapter 2, there was a fall in real energy prices between those years, a major expansion to the gas grid and the introduction of legislative restrictions on coal. But within the 1994-95 survey, fuel prices, infrastructure and regulations are approximately constant. However, it is arguable that, under these circumstances, the true or "long run" energy to income relationships ought to be more precisely observable.

Some explanation is perhaps required for the repeated references to total household expenditure as "income". The Household Budget Survey does record disposable household income as well as expenditures, but there are several reasons why an expenditure measure may be a better measure of true, long run, income. Many peoples' incomes fluctuate over time, especially if self-employed, and expenditure may be determined by expected, or average, income over a multi-year period, with saving or dissaving in sub-periods. Young people borrow on the strength of future earnings, while old people may draw on assets. There is also an understandable, if no doubt regrettable, tendency for at least some survey respondents to understate their incomes – a point discreetly made in the introductory notes to the Central Statistics Office's (1997) publication on the 1994-95 survey. Table 4.1 groups households by recorded gross household income deciles and compares average disposable incomes and expenditures.

For urban households expenditure substantially exceeds income for all income ranges except for the 10$^{th}$ decile (the highest stated incomes), when income and expenditure approximately equal. Of course, the reasons for discrepancies cannot be disentangled, but if incomes were being recorded accurately, saving (income exceeding expenditure) would be expected at high incomes, balanced by dissaving at low incomes. Expenditure also exceeded income on average for rural households, although this was reversed for the sub-sector of farm households, which had the highest average incomes. Since farm incomes vary from year to year, it is reasonable to expect saving in a "good" year and to interpret expenditure as the measure of long run income. So, for the rest of this report, "income" should be understood as measured by total household expenditure, unless there is a statement to the contrary.

**Table 4.1: Incomes and Expenditures of Households – £/week**

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Urban Households** | | | | | | | | | | | |
| decile | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean |
| income | 67 | 107 | 142 | 184 | 229 | 277 | 334 | 399 | 481 | 707 | 293 |
| expenditure | 83 | 128 | 179 | 228 | 271 | 332 | 384 | 440 | 533 | 705 | 328 |
| **Rural Households (including Farm Households)** | | | | | | | | | | | |
| decile | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean |
| income | 57 | 86 | 122 | 154 | 195 | 241 | 294 | 361 | 444 | 679 | 263 |
| expenditure | 93 | 113 | 146 | 190 | 244 | 282 | 337 | 394 | 459 | 576 | 283 |
| **Farm Households Only** | | | | | | | | | | | |
| decile | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | Mean |
| income | 50 | 104 | 149 | 195 | 235 | 280 | 349 | 429 | 551 | 861 | 320 |
| expenditure | 129 | | 177 | 243 | 150 | 273 | 343 | 400 | 410 | 596 | 298 |

The relationship between fuel expenditure and income can be visualised as a curve with the fuel expenditure as the vertical axis and income as the horizontal axis. By choosing some mathematical form for the curve, the relationship can be quantified and then employed for estimation or prediction. A range of functional forms have been recommended in the literature for fitting Expenditure-Income (Engel Curves) relationships. For the semi-log equation

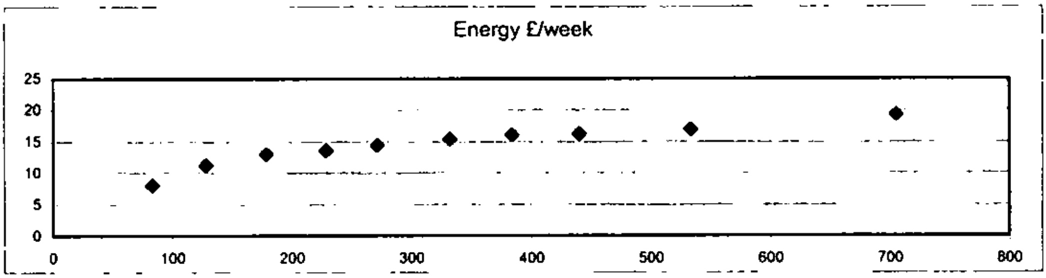
$$x = a + b\log(y) + e, \tag{4.1}$$

x is commodity expenditure, y is income, a and b are constants and e represents deviations from the relationship. This has often been found to fit well for commodities usually considered quite income inelastic, as total energy is, while the linear relation

$$x = a + by + e, \tag{4.2}$$

has often proved better for more income elastic commodities. The plausibility of the semi-log form (4.1) for total household fuel expenditures, for example, can be seen from Figure 4.1, which plots means corresponding to the urban income decile groups of Table 4.1.

**Figure 4.1: Household Energy Expenditures and Incomes for Urban Households**




## 4.2 The Income Elasticity of Energy Expenditure

As was mentioned in the Introduction, an important parameter of an expenditure-income relationship is the elasticity – that is, the percentage increase in energy consumption or expenditure given a one percent increase in income. The elasticity formulae are b/x for the semi-log (so that the elasticity decreases as energy consumption increases) and by/x for the linear (4.2). Although elasticities change with position along the curve, the elasticity at average income is usually the most useful summary statistic. This is because the aggregate energy expenditure of the whole household sector (which is just average expenditure multiplied by the number of households) is usually of main interest, so that the effect of change in average income is what matters.

For total household fuels, Table 4.2 shows both linear and semi-log relationships for the State as a whole, for urban and for rural areas. These equations have *not* been estimated by ordinary least squares, but through an instrumental variables approach, the need for which is explained in Appendix A.

**Table 4.2: Equations and Goodness of Fit Measures for Total Household Fuels**

| | $R^2$ | SEE | Constant | Coef. | t value | Mean Elasticity' |
|---|---|---|---|---|---|---|
| Semi-log – State | .98 | 13.0 | -11.63 | 4.80 | 21.21 | .32 |
| Linear – State | .89 | 31.4 | 9.87 | .016 | 8.10 | .34 |
| Semi-log – Urban | .98 | 11.1 | -12.3 | 4.76 | 19.56 | .33 |
| Linear – Urban | .86 | 28.6 | 9.22 | .016 | 7.17 | .35 |
| Semi-log – Rural | .94 | 14.3 | -13.50 | 5.35 | 11.72 | .33 |
| Linear – Rural | .91 | 17.1 | 10.31 | .021 | 9.83 | .37 |

Comparisons of the constants and coefficients of semi-log and linear are not meaningful, since they are different functional forms, but comparisons of $R^2$, SEE (Standard error of estimate) and t values are.[3] Clearly the semi-log is a better fit with higher explained variation and a much lower (for Urban) prediction error. This supports the suggestion from Figure 4.1 that the semi-log is

[3] Since the analysis was not OLS, these are non-standard, but can be used to compare rival models.

preferable. Choice of the linear form would have led to higher (though not by much) estimates of elasticities.

Some points in the table deserve discussion. The urban and rural elasticities are remarkably similar, but the elasticity for the whole State is lower than either of them, although it might have been thought more reasonable that it lie between them. The explanation is that the rural coefficient is larger than the urban one (although the relationship is poorer with a lower t value). The State coefficient is in between, but close to the urban value, because most of the survey sample was urban. On the other hand, Table 2.1 showed average rural energy expenditure exceeding average urban and, as already mentioned, the elasticity should fall as energy expenditure increases. So, although at any fixed level of energy consumption the elasticity would be higher for rural than for urban households, the elasticities are roughly equal because they are calculated at the respective average consumptions. The elasticity for the State is below that for urban because the overall average consumption is higher, while it is below the rural because its coefficient is smaller. The matter of why the coefficient (income response) should seem higher for rural areas, and whether this is really plausible, will be returned to.

## 4.3 The Effects of Household Size

The family composition of households could quite possibly affect energy consumption. A single variable, the number of persons in the household, is a considerable over-simplification of family composition, since it does not distinguish between adults and children, but it is a natural starting point. In the analyses that follow, household size is included as an explanatory variable with income. They are not uncorrected variables, as household income will rise on average with household size, partly because there may be more than one employed adult and also because adult incomes tend to rise with age (until retirement) and income earners in a household with children are likely to be older that in a childless household. For this reason some of the household size effect was already being captured by income in the analyses of the previous section and dramatic improvements in the fit of equations should not be expected. The semi-log functional form of equation is employed. The results are shown in Table 4.3.

**Table 4.3: Total Household Fuels – Income and Household Size Effects**

| | Inc. coef. | t value | Size coef. | t value | Inc. Elas. | Size Elas. |
|---|---|---|---|---|---|---|
| State | 4.01 | 6.95 | 1.19 | 1.33 ns | .27 | .08 |
| Urban | 3.96 | 8.11 | 1.45 | 1.88 ns | .28 | .10 |
| Rural | 5.75 | 3.63 | -.61 | -.29 ns | .36 | -.04 |

ns = not statistically significant.

The most evident feature from the table is the non significance of the household size coefficients and the corresponding size elasticities. The non significance of the positive size coefficient for urban areas is not surprising. Large economies of scale as regards overall household energy (A house that is kept warm enough for two is warm enough for three, etc.), are to be expected. In addition, the fact that income increases with family size introduces a collinearity effect that would be expected to reduce evidence of a statistically significant size effect. The urban size elasticity in Table 4.3, though low, is not implausible. For rural households, however, the coefficient and elasticity are negative, although not statistically significantly so, and this suggests that more detailed investigation is desirable by disaggregating household energy into its component fuels and then relating to income and household size. It should be said here that for some commodities it is not implausible that size effects could be negative. An extra child increases household size, but implies financial commitments that could reduce expenditures on luxuries. However, if energy is not a luxury, but a necessity, negative size effects are hard to believe.

An associated feature is that while the income elasticity for urban decreases a little from .33 in Table 4.2 to .28 in Table 4.3, that for rural increases from .33 to .36. The urban change is plausible, because controlling for household size reduces income variation, since they are correlated, but the rural change is not (although again it is not statistically significant). The explanations will emerge in the next chapter, when expenditure on electricity is analysed in detail.

## 4.4 More Elaborate Regression Analyses

Many more variables could be inserted into the regression equations as well as income, household size and rural versus urban. Dummy variables can cater for qualitative variables such as region, social class, family composition, type of dwelling, etc. However, the method of analysis described in the Appendix will fail when many variables are involved and coefficients have to be estimated by ordinary least squares, in spite of its defects. These estimations were performed and do have value for answering certain questions, but it is worthwhile discussing why they are often not very useful and why they will not be described in detail in this report.

The income elasticity will decrease as more variables related to income are controlled for. In the previous section household size was controlled for and that reduced the (urban) elasticity somewhat. However, although looking at the income effect holding household size constant may often make sense, controlling for other factors may only rarely do so. Social group is such a factor, because a major difference between the groups "higher professional" and "unskilled manual" is income level. Including both income and Social Group in a regression analysis could be justified if the matter at issue is whether there are differences between social groups other than due to income, or how much income related variation remains within a social group. However, estimating an income elasticity from the residual variation having eliminated the differences due to such factors will rarely be worthwhile. The point may be clearest in a forecasting context. To deduce the effect on energy demand of a forecast income increase is easy enough given a simple energy – income relationship summed up in an income elasticity. But to work from an equation in many variables requires forecasting all those variables too, taking account of how they relate to income.

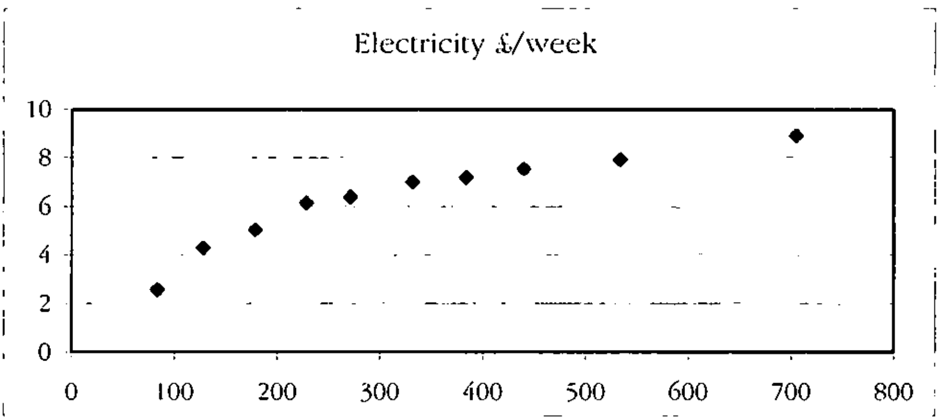
Similar remarks apply to factors like size and type of dwelling. At least in urban areas, these factors are not exogenous, but income dependent. Rather than perform a regression of household energy expenditure on all variables, an ideal model would have as many equations as endogenous variables (energy expenditure, size and type of dwelling etc.) with these related to the exogenous variables (income, regional location, family composition, etc.). But while such a model would be very useful, it could not be estimated from the data from just a single household budget survey, because the exogenous variables include prices. For example, the probability of purchase of a detached house rather than a semi-detached will depend on relative price as well as on variables like income and family size. Price variation is required to estimate coefficients for prices, but prices are fixed in the survey period.

# 5. ELECTRICITY EXPENDITURE, INCOME AND HOUSEHOLD SIZE RELATIONSHIPS AND FREE ALLOWANCES

## 5.1 Initial Elasticity Estimates

Although unexpected results will quickly become evident, it is best to commence with the same approach employed in the previous chapter. Figure 5.1 plots electricity (urban) expenditures against incomes.

**Figure 5.1: Electricity Expenditures and Incomes for Urban Households**




The figure shows that for electricity the diminishing response, typical of the semi-log form, is very much in evidence. Statistical tests seem to confirm the better fit of a semi-log rather than linear equation and estimating the former gives the equations shown in Table 5.1.

**Table 5.1: Expenditure- Income Equations for Electricity**

| | Constant | Coef. | t value | Mean Elasticity |
|---|---|---|---|---|
| Semi-log-State | -11.22 | 3.11 | 27.76 | .51 |
| Semi-log-Urban | -9.60 | 2.81 | 23.94 | .44 |
| Semi-log-Rural | -14.33 | 3.71 | 58.64 | .63 |

The mean elasticity for rural households is higher than for urban households, because the regression coefficients were correspondingly different. That for rural had standard error .063 and that for urban had standard error .117, so the difference is statistically significant by a t test. The implication would be that an increase in rural incomes would lead to a substantially greater increase in electricity expenditure than would a corresponding increase in urban household incomes. This seems to at least require explanation, but the further analyses including family size are even less credible. These are given in Table 5.2.

**Table 5.2: Income and Household Size Effects – Electricity Expenditure**

| | Inc. coef. | t value | Size coef. | t value | Inc. Elas. | Size Elas. |
|---|---|---|---|---|---|---|
| State | 2.72 | 10.75 | .67 | 1.72 ns | .44 | .11 |
| Urban | 2.19 | 11.96 | .95 | 3.10 | .37 | .15 |
| Rural | 4.02 | 22.92 | -.52 | -2.15 | .68 | -.10 |

ns = not statistically significant.

The income elasticity is now almost twice as large for rural as for urban, which would seem to require explanation. The size coefficients are statistically significant for both urban and rural, but of opposite sign. As was mentioned in the previous chapter, negative size effects are not unreasonable for luxuries, but electricity would usually be thought a necessity. However, there are some negative effects through demand for electricity being a derived demand. At fixed income, an extra member of a household may imply more expenditure on food, clothing etc. and therefore forgoing some luxury consumer durable, which may be electrically powered. Perhaps such negative size effects could more than offset the positive effects arising from provision of services (lighting, etc.) to an extra person, especially if the latter display large economies of scale. It is hard to see, however, why this should hold for rural and not for urban households.

At least part of the explanation for these phenomena can be sought in the existence of a free electricity allowance.

## 5.2 The Free Electricity Allowance

The free electricity allowance scheme was introduced in 1967. Qualifying households do not pay the standing charge (meter rent) and obtain 1500 free units of electricity per annum – 200 per period (of two months) in Summer and 300 per period in Winter. As units unused within a period can be transferred forward, the allowance could be expected to be fully utilised. Electricity expenditure is measured in the Household Budget Survey on the basis of the Electricity Supply Board's bill for the most recent two month period and so zeros can easily arise for households with the free electricity allowance, that are interviewed in Summer. Indeed, inspection of the original data reveals many zero electricity expenditures and very many minute expenditures, where the free allowance was just exceeded. Over the years, the number of households entitled to the allowance has increased and in 1997 exceeded 211 thousand. The corresponding payment to the ESB from the Department of Social, Community and Family Affairs was close to £30 million.

The eligibility conditions (detailed, for example, in DoSCFA, 1998) imply that most households with the allowance comprise pensioners, aged over 65 and dependants, although there are other qualifying categories too. These include some recipients of disablement and invalidity welfare payments, deserted wives allowances, lone parents allowances and various other groups. All of these households could qualify for an alternative free piped gas allowance (if connected for gas, or vouchers for LPG otherwise), but few make this choice. It should be mentioned here that there are also fuel allowances payable along with weekly assistance to low income households, but being cash payments and spent like any other income, these do not distort measures of fuel expenditures.

To understand the impact of the free electricity scheme on the estimation of income elasticities, it is necessary to look at the distribution of the allowance. Its frequency of occurrence in the 1994/95 Household Budget Survey, by urban and rural areas, is illustrated in Table 5.3.

**Table 5.3: Prevalence of the Free Electricity Allowance in the 1994/95 Survey Households**

| | Urban | Rural-Non Farm | Farm | State |
|---|---|---|---|---|
| % Elect. Allow. | 16.9 | 26.1 | 6.8 | 18.1 |
| % Gas Allow. | .5 | 0 | 0 | .3 |
| % No Allow. | 82.6 | 73.9 | 93.2 | 81.6 |
| No. Households | 5,066 | 1,953 | 858 | 7,877 |

There is a substantially higher frequency of allowances in rural non-farm households than in urban ones. A breakdown of households with allowances by gross weekly household income is given in Table 5.4.

**Table 5.4: Free Electricity by Gross Weekly Household Income**

| Income £/week | <50 | 51-110 | 111-170 | 171-230 | 231-290 | 290-400 | >400 |
|---|---|---|---|---|---|---|---|
| % Elect. Allow. | 17 | 55.8 | 33.6 | 12.3 | 8.9 | 2.5 | .6 |
| % Gas Allow. | 0 | .6 | 1.1 | .1 | 0 | .2 | 0 |
| % No Allow. | 83 | 43.6 | 65.3 | 87.6 | 91.1 | 98.3 | 99.4 |
| No. Households | 75 | 1,437 | 1,198 | 835 | 666 | 1,106 | 2,560 |

By far the greater number of allowance holding households are in the lower (but not the lowest) income groups, although there is some representation in the higher income categories. Turning to household composition, Table 5.5 shows the breakdown. The compositions considered are: single adult under 65 years of age (A<65), single adult over 65 (A>65), married couple without children in the household (M2A), married couple with one or more children (2A+C's), single adult with one or more children (A+C's) and other households (Other).

**Table 5.5: Free Electricity by Household Composition**

| | A<65 | A>65 | M2A | 2AC+C's | A+C's | Other |
|---|---|---|---|---|---|---|
| % Elect. Allowance | 8.1 | 81.7 | 31.7 | 1.1 | 1.8 | 7.3 |
| % Gas Allowance | .1 | 1.5 | .4 | 0 | 0 | .2 |
| % No Allowance | 91.8 | 16.8 | 67.9 | 98.9 | 98.2 | 92.5 |
| No. Households | 839 | 992 | 1,101 | 2,355 | 327 | 2,263 |

The free electricity allowance is most common for single adults aged over 65 and quite frequent for married couples without children, which, of course, is to be expected given the eligibility of many pensioners. Very few households with children have the allowance. However, the numbers with the allowance are still appreciable for single adults under 65 and for the "Other" households.

It is now possible to see what happens in estimating income elasticities. From Table 5.4, households with the allowance are predominantly of lower income. So there will seem to be a large initial response of electricity expenditure to increasing income, which is really due to the reduction in proportion of households with allowances. The response to further income increases will be more modest. We can expect the overall income elasticities to be somewhat exaggerated and at least part of the semi-log shape, as observed in Figure 5.1, to be spurious. These distortions will be larger for the rural households, where (Table 5.3) possession of allowances was higher.

The effects on household size elasticities are more complicated. Holding (low) income fixed, an increase from one to two in household size is associated (Table 5.5) with a reduction in the proportion of allowances. With further increases in size to households with children, the allowance virtually disappears. This suggests standard estimation will exaggerate the size effect. Of course, at higher incomes the proportions of households with the allowance are low and the effect is slight, but, on average, some overestimation should result. Something like this probably applies to estimation for urban households. Rural households include farms and it is well known that bachelor farmers comprise much of the lower income segment of that profession. Many such farmers will have equal incomes to non-farm rural pensioner couples. However, Table 5.3 showed that few farmers, unlike pensioners, hold free electricity allowances, so the single person farm household could have higher electricity expenditure than the larger household. This would tend to produce a negative size effect. This effect may be being heightened by the fact that, even without the allowance, rural non-farm households spend less on electricity than farm households of equal income and size.[4] Other mechanisms through which a (spurious) negative size effect could be produced can also be visualised.

## 5.3 Correcting the Elasticity Estimates

Appreciating that elasticities are wrong and why, does not in itself solve the problem of how to correct them. The various possible approaches are described in Conniffe (2000), where the best option was considered to involve the imputation of extra electricity expenditure *and* income to allowance holders. That is, the value of the 1500 free units plus the remission of the standing charge, expressed as a weekly sum (£2.75) is added to all allowance holders' electricity expenditures and to their incomes before fitting the Engel curve. However, the validity of applying this procedure can be shown to depend greatly on there being relatively few households that would have consumed less than 1500 units without the allowance. Conniffe (2000) estimates the frequency of such households and in the process estimates upper bounds to the welfare loss and unwanted electricity production that may be implicit[5] in a free electricity scheme. The paper shows that the frequency of such households is indeed low enough to justify the imputation estimation method.

Re-estimated equations and elasticities, ignoring household size effects are shown in Table 5.6.

**Table 5.6: Expenditure – Income Equations for Electricity**

| | Constant | Coef. | t value | Mean Elasticity |
|---|---|---|---|---|
| Semi-log – State | -7.31 | 2.43 | 6.62 | .35 |
| Semi-log – Urban | -6.49 | 2.29 | 9.89 | .33 |
| Semi-log – Rural | -9.78 | 2.91 | 4.75 | .41 |

Comparing back to Table 5.1, the coefficients and elasticities are much smaller and the urban and rural values are closer together with their difference no longer statistically significant. Table 5.7 gives the corresponding results when the household size variable is included.

[4] There are possible complexities here. Farmers, unlike other businessmen, record home and business electricity use on the same metre. So the CSO obtain household electricity expenditure by subtracting estimates of use as inputs to farm enterprises. These estimates are supplied from Teagasc's Farm Management Survey. Any estimation errors or biases feed into the household figures.

[5] These arise because a low income household, that would have consumed below 1500 units if without free electricity, would probably prefer a direct income transfer to the value of the electricity allowance, because some could be spent on preferred commodities. The paper found these losses to be very small in 1994-95, although they may not have been so in the past. (The number of free units of electricity has not changed since the 'sixties although incomes have risen greatly. In addition the variety of electrically powered appliances was considerably smaller then.) They might not remain so in the future, either, if the number of free units was to be substantially increased.

**Table 5.7: Income and Household Size Effects – Electricity Expenditure**

| | Inc. coef. | t value | Size coef. | t value | Inc. Elas. | Size Elas. |
|---|---|---|---|---|---|---|
| State | 2.40 | 6.11 | .46 | .48 ns | .35 | .07 |
| Urban | 2.28 | 9.79 | .58 | .96 ns | .33 | .08 |
| Rural | 3.20 | 3.96 | -.72 | -.43 ns | .45 | -.10 |

ns = not statistically significant.

Again comparing back to Table 5.2, the income coefficients and elasticities are smaller and no longer statistically significantly different between urban and rural. The formerly significant positive coefficient for the urban size effect is no longer so, although still positive. The rural size effect still has the negative sign, but the coefficient is now statistically insignificant. While, as noted earlier, there could still be residual problems related to estimation of expenditures in farm households, perhaps responsible for the negative sign, an overall finding of a statistically insignificant size effect is not implausible. Although larger households will tend to use more electricity, substantial economies of household scale in electricity use seem likely. In addition, at fixed household income, families with children incur extra necessary expenditures and this must, to some extent, prevent the acquisition of some electrically powered luxury consumer durables.

The semi-log form was retained in these tables for consistency in making comparisons, although there was no real statistical advantage over the linear functional form. The latter was actually a slightly better fit for urban data, although slightly worse for rural households. It appears that much of the original non-linearity derived from treating the apparent expenditures of allowance holding households on the same basis as other households.

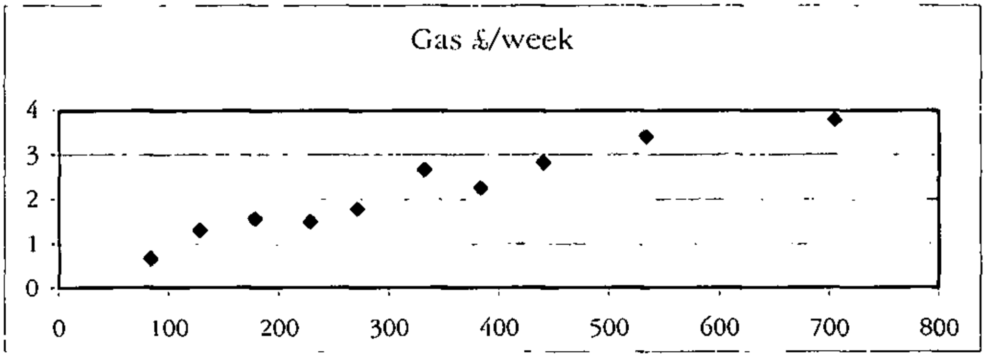
A final analysis of some interest is to include the index of electrical appliances, which was described in Chapter 2, as an extra variable in the regression. Since demand for electricity derives from possession of electrically powered appliances, controlling for the stock of appliances might be expected to reduce the income elasticity greatly, perhaps even to insignificance. Adding the index does reduce the elasticity substantially, but it is still significantly above zero. It is unclear how much of this residual relationship is due to greater use of possessed appliances with increasing income, or to the inadequacy of the index as an ideal measure of the stock of appliances. For forecasting or other applications, however, it is of course the unreduced elasticities of Table 5.6 that matter.

# 6. The High Elasticity Fuels – Gas and Oil

## 6.1 Gas Elasticities

There is a free piped gas scheme, analogous to the free electricity allowance, but alternative to it. As was shown in the previous chapter few consumers avail of it, so the resultant complications do not arise. Based on a division of urban households by income deciles, Figure 6.1 plots the gas expenditure to income (total expenditure) relationship.

**Figure 6.1: Gas Expenditures and Incomes for Urban Households**




The figure is at least as supportive of a linear curve as a semi-log and Table 6.1 confirms this. It should be mentioned again here that the $R^2$ in the table, while appropriate for comparing the functional forms is not the standard OLS $R^2$ and overstates goodness of fit. Since gas is essentially an urban fuel, the rows for State and Rural, employed in the case of electricity, are omitted here.

**Table 6.1: Equations and Goodness of Fit Measures for Gas**

| | $R^2$ | SEE | Constant | Coef. | t value | Mean Elasticity |
|---|---|---|---|---|---|---|
| Semi-log – Urban | .91 | 6.98 | -5.85 | 1.43 | 9.2 | .66 |
| Linear – Urban | .94 | 5.85 | .54 | .005 | 11.0 | .75 |

Chapters 2 and 3 discussed the importance of central heating as a determinant of gas consumption and so it is not surprising that an analysis (not displayed) including possession of central heating as an additional explanatory variable (that is, controlling for possession) gave far lower income elasticities, showing that most of the increased consumption of gas at higher incomes results from installation of gas central heating. However, this has probably already been treated in sufficient detail in Chapter 3. Adding household size to the linear equation gives the results shown in Table 6.2.

**Table 6.2: Income and Household Size Effects – Gas Expenditure (Urban Areas)**

| | Inc. coef. | t value | Size coef. | t value | Inc. Elas. | Size Elas. |
|---|---|---|---|---|---|---|
| Urban | .0045 | 5.86 | .114 | .73 | .68 | .17 |

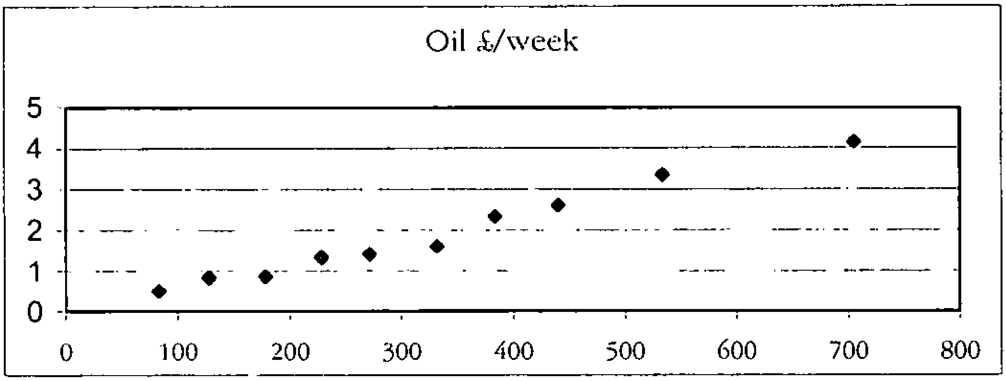
ns = not statistically significant.

The size coefficient is not statistically significant and comparison with Table 6.1 shows that adding household size has not appreciably altered the income coefficient in the linear equation. This is reasonable enough given that gas is largely a central heating fuel, and substantial economies of household scale could be expected.

## 6.2 Oil Elasticities

A plot of oil expenditures on income is shown in Figure 6.2, again for urban households.

**Figure 6.2: Oil Expenditures and Incomes for Urban Households**




The relationship appears much closer to linear than to semi-log and this is supported by the coefficients of determination and standard errors of estimate given in Table 6.3.

**Table 6.3: Equations and Goodness of Fit Measures for Oil**

| | $R^2$ | SEE | Constant | Coef. | t value | Mean Elasticity |
|---|---|---|---|---|---|---|
| Semi-log – State | .86 | 13.7 | -7.54 | 1.74 | 6.90 | .81 |
| Linear – State | .98 | 5.0 | .09 | .0066 | 20.49 | .96 |
| Semi-log – Urban | .86 | 10.6 | -7.42 | 1.66 | 6.96 | .87 |
| Linear – Urban | .98 | 3.8 | -.09 | .0061 | 20.58 | 1.05 |
| Semi-log – Rural | .83 | 10.2 | -8.73 | 2.06 | 6.16 | .81 |
| Linear – Rural | .95 | 5.2 | .15 | .0085 | 12.94 | .94 |

With elasticity values of about unity, oil is the most income responsive of all fuels. However, this is entirely associated with the high income elasticity of central heating. When possession of central heating is controlled for by adding an appropriate dummy variable to the regression, income elasticities drop to nearly zero and are not statistically significant. Adding the household size variable into the linear equation gives the results shown in Table 6.4.

**Table 6.4: Oil Expenditure – Income and Household Size Effects**

| | Inc. coef. | t value | Size coef. | t value | Inc. Elas. | Size Elas. |
|---|---|---|---|---|---|---|
| State | .0075 | 15.2 | -.182 | -2.14 | 1.09 | -.28 |
| Urban | .0066 | 14.0 | -.125 | -1.31ns | 1.13 | -.21 |
| Rural | .0114 | 9.93 | -.407 | -2.82 | 1.27 | -.51 |

ns = not statistically significant.

Income elasticities have increased somewhat compared to Table 6.3 and the size elasticities for both urban and rural areas are negative, significantly so for the latter. Unlike in the case of electricity, these negative signs are not surprising. Economies of household scale were to be expected, given that oil is a central heating fuel, which would suggest that effects, if positive, would be small. But because the income elasticities are greater than unity, making oil technically a "luxury", another effect operates. Much of the measured effect of size is the effect of children in the household. Children imply certain commitments and divert expenditures towards necessities. At a given level of income a couple with a child, as compared with a childless couple, have less discretionary income to devote to "luxuries". In the case of oil, what happens is that although a childless couple on a certain income can afford to install central heating, parents of children cannot at that income.

The income coefficient for rural areas is significantly greater than for urban and that makes sense too. Since central heating is seen as highly desirable, an increase in income leads to installation and in rural households that implies oil as a fuel. But in urban areas a gas system may be installed. The fact that the elasticities do not seem to fully reflect the differences in coefficients is because elasticities (of linear relationships) increase with incomes and these are higher in urban areas. The higher negative coefficient for size in rural areas (which is reflected in the elasticities) can be similarly explained. If, because of the cost of children, parents in a rural household cannot afford to install central heating, an amount of oil is not purchased. But in an urban area the central heating, could it have been afforded, might have been a gas system in the first place.

## 6.3 Elasticity Use in Forecasting

Given forecasts, or scenarios, for future household income, composition and location, these elasticity estimates can be easily employed to deduce household demands for gas and oil. The quite important moderating size effect for oil in rural areas shows that demographic changes could be important. However, to put the utility of these estimates in proper perspective, it is worth remembering the evidence of Chapter 3. Demands for both gas and oil are driven by demand for central heating. Possession of central heating has a high income elasticity and tables suggested the 1994/95 housing stock was well short of saturation – a picture that received support from the corresponding figures for Northern Ireland in 1996 as reported in Section 3.5.

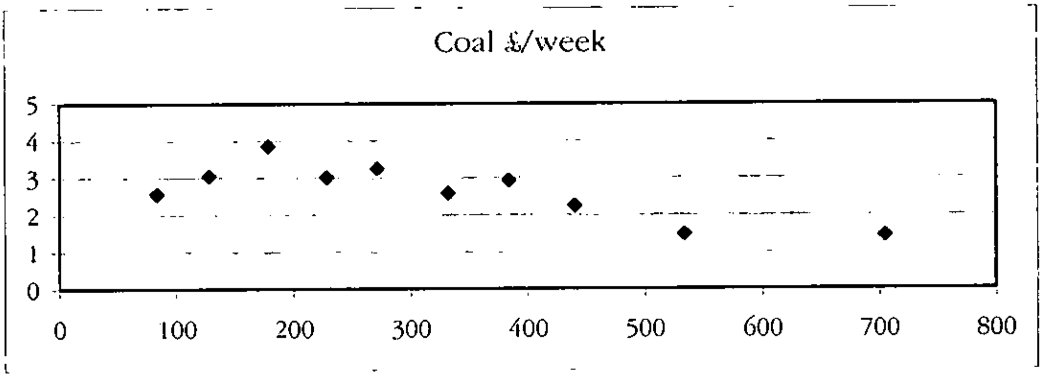
However, the frequency of central heating had increased substantially from the previous round of the Household Budget Survey in 1987 and the substantial income increases of recent years must have accelerated its acquisition. As pointed out in Section 3.3, very few recently constructed dwellings lack central heating. So as central heating approaches saturation within existing housing, gas and oil elasticities will be largely determined by the income elasticity of the housing stock and the location of new housing.

# 7. THE INFERIOR FUELS – COAL, TURF AND LPG

## 7.1 Coal Elasticities

The relationship of expenditure to income for the three fuels considered here will contrast greatly with that for the two high elasticity fuels considered in the previous chapter and indeed with that for electricity. Figure 7.1 shows expenditures on coal for urban households by income deciles.

**Figure 7.1: Coal Expenditures and Incomes for Urban Households**




Clearly there is no point investigating whether there is a semi-log or linear increasing relationship with income. A decrease with income (except, perhaps, at low incomes) is indicated. Fitting a linear income decrease gave income elasticity estimates of -.29, -.38 and -.11 for State, Urban and Rural respectively. The analyses are not shown in detail, but those including the household size variable revealed some interesting aspects and are displayed in Table 7.1.

**Table 7.1: Coal Expenditure – Income and Household Size Effects**

| | Inc. coef. | T value | Size coef. | t value | Inc. Elas. | Size Elas. |
|---|---|---|---|---|---|---|
| State | -.0049 | -4.57 | .48 | 2.60 | -.56 | .58 |
| Urban | -.0055 | -5.48 | .62 | 3.03 | -.69 | .76 |
| Rural | -.001 | -.46 ns | -.01 | -.02 ns | -.10 | -.01 |

ns = not statistically significant.

For urban households there is a significant decrease in coal expenditure with increasing income and consequently the income elasticity is negative, making coal technically an "inferior" good.

The urban size effect is statistically significant and positive, which makes sense. As incomes increase households switch away from coal, presumably because they can afford to install heating systems that use oil or gas. But households with children or other dependants will not be able to afford this step at income levels where smaller households could. For rural households, neither income nor household size are significantly related to coal consumption. The absence of a significant decline similar to that for urban areas may have something to do with solid fuel central heating. Table 3.8 has shown this to be more frequent in rural households, although it was far from being as popular as oil. The legal restrictions on smoky coal in urban areas may be a factor in the difference. Lower income households may have stayed with coal, by substituting the more expensive smokeless coal (and claiming the fuel allowance provided for the purpose), while higher income households switched to central heating. The large difference between the income elasticity ignoring household size and that taking it into account is, of course, due to the large size effect.

## 7.2 Turf Elasticities

The picture for turf is very similar to that for coal. Figure 7.2 illustrates urban expenditures on turf. Again, there is the tendency to decline with increasing income, although it is not a closely fitting relationship. The income elasticities were estimated as -.30, -.31 and -.12 for State, Urban and Rural respectively. Taking household size into account, gives a similar results to those obtained for coal as the analyses in Table 7.2 show.

**Figure 7.2: Turf Expenditures and Incomes for Urban Households**

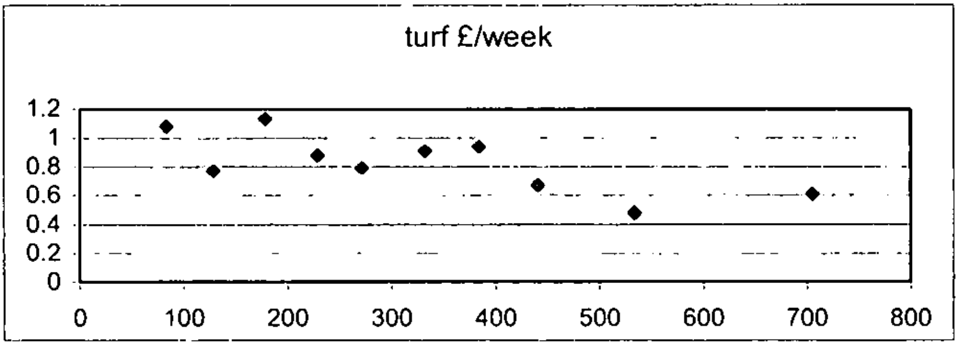



**Table 7.2: Turf Expenditure – Income and Household Size Effects**

| | Inc. coef. | T value | Size coef. | t value | Inc. Elas. | Size Elas. |
|---|---|---|---|---|---|---|
| State | -.0023 | -3.54 | .14 | 1.98 ns | -.43 | .28 |
| Urban | -.0009 | -2.09 | .04 | .39 ns | -.37 | .14 |
| Rural | -.0050 | -3.69 | .52 | 2.53 | -.45 | .55 |

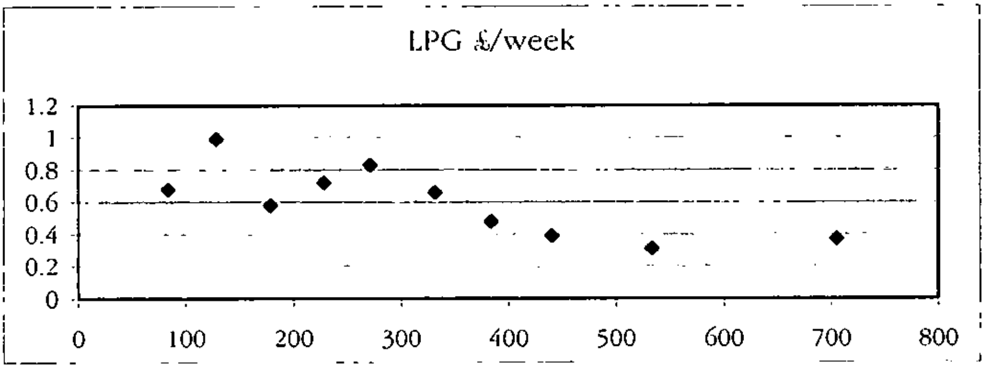
ns = not statistically significant.

As before, income coefficients and elasticities are negative, while those for size are positive and similar interpretations apply. The size coefficient for urban is not actually statistically significant and that for income is only just. As was evident from Table 2.1, Turf is a relatively unimportant fuel in urban areas and so the overall pattern for the State is dominated by the rural relationship, where Turf is still an important household fuel.

## 7.3 LPG Elasticities

LPG is the least important fuel overall, although it is relatively more important in rural areas, where piped gas is unavailable. Figure 7.3 shows expenditures and incomes for urban areas.

**Figure 7.3: LPG Expenditures and Incomes for Urban Households**




Again there is an erratic scatter at low incomes before definite decline at higher incomes for these urban households. The income elasticities for State, Urban and Rural are estimated as -.32, -.48 and -.05. Table 7.3 again includes the household size variable in the same way as for the other fuels.

**Table 7.3: LPG Expenditure – Income and Household Size Effects**

| | Inc. coef. | T value | Size coef. | t value | Inc. Elas. | Size Elas. |
|---|---|---|---|---|---|---|
| State | -.0011 | -2.45 | .04 | .55 ns | -.39 | .16 |
| Urban | -.0010 | -2.19 | .02 | .21 ns | -.52 | .10 |
| Rural | -.0008 | -.81 ns | .08 | .63 ns | -.18 | .20 |

ns = not statistically significant.

Again, elasticities are negative for income and positive for size, but the latter were not statistically significant and the income effect was not significant for the rural sector. This absence of decline with income is perhaps related to the unavailability of piped gas.

# 8. Summarising and Comparing Elasticities

## 8.1 Correcting the Overall Elasticities

A remaining task is to correct the overall energy elasticities, derived in Chapter 4, for the effects of the overestimation of the electricity income elasticity. The income elasticity of fuel j is

$$E_J = \frac{y}{x_j}\frac{\partial x_j}{\partial y}$$

where y is income and $x_j$ is expenditure on fuel j. Total, or overall, energy expenditure is $\Sigma\, x_j$ and its income elasticity is

$$E_T = \frac{y}{\Sigma x_j}\frac{\partial \Sigma x_j}{\partial y} = \frac{y}{\Sigma x_j}\left\{\frac{\partial x_1}{\partial y} + \frac{\partial x_2}{\partial y} + \frac{\partial x_3}{\partial y} + \frac{\partial x_4}{\partial y} + \frac{\partial x_5}{\partial y} + \frac{\partial x_6}{\partial y}\right\}$$

$$= \frac{x_1}{\Sigma x_j}E_1 + \frac{x_2}{\Sigma x_j}E_2 + \frac{x_3}{\Sigma x_j}E_3 + \frac{x_4}{\Sigma x_j}E_4 + \frac{x_5}{\Sigma x_j}E_5 + \frac{x_6}{\Sigma x_j}E_6$$

$$= W_1E_1 + W_2E_2 + W_3E_3 + W_4E_4 + W_5E_5 + W_6E_6,$$

where the W's are the proportions of expenditure spent on the fuels. There are different sets, of course, for urban, rural and the whole State. Then the overall elasticities at average household income can be obtained by using the proportions from Table 2.1.[6] In the computation the urban gas elasticity can be used for rural and State, because the weighting by proportion (zero for rural) will take care of the fact that it is an urban fuel. Exactly the same approach applies to household size elasticities. Carrying out the calculations leads to the elasticities in Table 8.1.

[6] It is true the electricity expenditure in Table 2.1 does not include the free allowance, but the further correction would be very minor.

**Table 8.1: Adjusted Elasticities for Overall Household Energy**

| | State | Urban | Rural |
|---|---|---|---|
| Income ignoring household size | .25 | .29 | .25 |
| Income allowing for household size | .19 | .23 | .25 |
| Household size allowing for Income | .15 | .18 | .01 |

For ease of comparison the original estimates derived in Chapter 4, and given in Tables 4.2 and 4.3, are presented again in Table 8.2.

**Table 8.2: Initial Estimated Elasticities for Overall Household Energy**

| | State | Urban | Rural |
|---|---|---|---|
| Income ignoring household size | .32 | .33 | .33 |
| Income allowing for household size | .27 | .28 | .36 |
| Household size allowing for Income | .08 | .10 | -.04 |

For income elasticities ignoring household size (this is the "usual" income elasticity, which averages over households of varying sizes), the adjusted values are lower than the original as would be expected. Taking account of household size, the adjusted income elasticities are also lower than the initial and the urban and rural values are little different, whereas originally rural had seemed substantially higher than urban. Both adjusted size elasticities are positive (although the value for rural is small), while initially the urban was positive and the rural negative.

## 8.2 Summarising the Income Elasticities

For convenience, the income elasticities for all fuels are summarised in Table 8.3. Although mentioned in Chapter 4, it probably bears repeating here that income elasticities estimated at a fixed time point within a household budget survey are not necessarily the same as estimates made over time. Ideal data would come from an annually repeated budget survey. Nonetheless, the estimates in Table 8.3 are likely to be far better for most purposes than elasticities deduced from just a couple of widely separated time points. For example, Table 2.2, showed that income increased by 15.5 per cent between 1987 and 1994, while energy expenditure rose by 5.3 per cent that would "imply" an income elasticity of .34, perhaps not too different from the survey estimate.

**Table 8.3: Summary of Income Elasticities**

| Income Elasticity of: | State | Urban | Rural |
|---|---|---|---|
| Overall energy expenditure | .25 | .29 | .25 |
| Gas expenditure | Na | .75 | Na |
| Electricity expenditure | .35 | .33 | .41 |
| Coal expenditure | -.29 | -.38 | -.11 |
| Turf expenditure | -.30 | -.31 | -.12 |
| Oil expenditure | .96 | 1.05 | .94 |
| LPG expenditure | -.32 | -.48 | -.05 |

But similar reasoning for gas and coal, say, would have implied elasticities of 6.3 and -2 respectively! The reasons, of course, are that other factors such as the expansion of the gas grid and restrictions on smoky coal have occurred over the period.

## 8.3 Previous Household Budget Survey Estimates

It may be worth comparing the elasticities found for this 1994-95 Household Budget Survey with estimates obtained for past surveys by other authors. Leser (1964) estimated elasticities from the 1951-52 HBS, Pratschke (1969) replicated these using the 1965-66 HBS, Murphy (1975-76) did likewise for the 1973 survey and Conniffe and Scott (1990) reported elasticities from the 1980 and 1987 rounds of the HBS. The authors did not have identical breakdowns of fuels – Pratschke and Murphy ran oil and LPG together as "other fuels" and Leser also included turf in this category. It is very likely that "free electricity bias" has been operating in all surveys since, and including, 1973. The effects were unfortunately not appreciated by authors, although even if they had been, remedial action would not have been feasible without access to the survey data at household level. Such data were not made available in the past. The estimates are given in Table 8.4 and (except for Gas, which is obviously urban based) correspond to "Whole State" values, except for the earliest HBS, which was urban only. The 1994-95 estimates are, of course, those corrected for the free electricity allowance.

**Table 8.4: Elasticity Estimates from Rounds of the Household Budget Survey**

| HBS | 1951-52 | 1965-66 | 1973 | 1980 | 1987 | 1994-95 |
|---|---|---|---|---|---|---|
| Total Fuels | .50 | .32 | .46 | .48 | .43 | .25 |
| Gas | .48 | .47 | .20 | .44 | .37 | .75 |
| Electricity | 1.01 | .82 | .87 | .72 | .76 | .35 |
| Coal | .59 | .08 ns | .06 ns | .02 ns | -.01 ns | -.29 |
| Turf | na | .51 | -.69 | -.55 | -.50 | -.30 |
| Oil | na | na | na | 1.54 | 1.85 | .96 |
| LPG | na | na | na | .01 ns | -.50 | -.32 |
| Other | -.06 ns | .10 | .86 | na | na | na |

ns = figure not statistically significantly different from zero.
na = not applicable.

Over time, there have not been the steady reductions in elasticities that might be expected of an inelastic commodity given steadily rising average income, except perhaps for electricity. The derived demand nature of energy consumption is responsible for some patterns. Oil is a central heating fuel and centrally heated houses were rare in Ireland before the late 1960s. So the elasticity for "Other" fuel is low until the 1973 survey (oil, presumably, being then the dominant component) and the subsequent oil elasticities are very high. The relative fall in value from 1987 to 1994 is largely because of the emergence of natural gas as a central heating fuel. In the earlier surveys, manufactured town gas was largely a cooking fuel and high income urban households often did not have gas connections, but this situation has changed greatly since the mid-1980s. Coal and turf are low-income fuels and, with the passage of time, have changed from having low income elasticities to actually declining with income.

As regards the electricity elasticity, had the distorting effect of the free scheme been absent, the values might well have declined steadily in "classic" fashion. In the 1950s the elasticity was unity or above, making electricity a "luxury", because many electrical appliances (refrigerators, for example) were not common in low income households. Nowadays, such appliances are seen as necessities and the relative variation in electricity consumption from low to higher income households is much less. Although the elasticity had dropped by 20 per cent by the 1965/66 Household Budget Survey, it had actually increased a little by the 1973 survey and declined by relatively little until this most recent survey. It is very likely that the introduction of the free scheme in 1967 biased estimates upwards. If the degree of bias operating in 1987 was the same as found in this study (the .51 elasticity estimate of Table 3.1 as compared with the .35 figure in Table 8.3), the elasticity then should have been .49 rather than .76. Because the electricity bias feeds through, though diluted by the other fuels, into the elasticity estimates for total household energy, the drop from 1987 to 1994/95 is exaggerated. Adjusting the 1987 figure in the same manner, would give .32. Some of the increase in elasticity between 1965/66 and the 1973 surveys is also a manifestation of the bias, but much of it must be the oil and central heating effect, that has already been mentioned.

To complete this discussion some comments on the long term applicability of the current elasticity values and the derivation of future estimates are appropriate. The elasticities shown in Table 8.3 can be used, at least in the short term, for forecasting the increased national energy and fuel demands by the household sector consequent on predicted income growth. As mentioned in Chapter 5, there could have been bias in the estimation of electricity demand, even with the adjusted (imputation based) elasticities, had there been more than a very small proportion of households that would have used less than 1500 units without the allowance. However, that could conceivably change in the longer term. Future demographic patterns and allowance eligibility conditions could combine to considerably increase the proportion of households with allowances. If there should also be any substantial increase in the size of allowance (number of units), there would be estimation bias in predicting electricity demand. Of course, elasticity estimates are likely to be re-estimated after every new round of the HBS, but that future estimation and subsequent prediction should take full account of the free electricity allowance as it then will be.

# 9. Summary of Findings and their Relevance to Energy Policy

## 9.1 Conclusions Summarised

For the households surveyed in the 1994-95 round of the Household Budget Survey, energy expenditure averaged £15 per week, or 4.8 per cent of total household expenditure. Of the six fuels – piped gas, electricity, coal, turf, oil and LPG – involved in household energy consumption, expenditure was largest on electricity, being over 40 per cent of the total. Between 1987 and 1994 energy expenditure increased by 5.3 per cent in real terms, compared with a 15.5 per cent increase in total household expenditure, but this masks more dramatic changes between sectors and fuel shares. For urban households energy expenditure increased by just a little over 1 per cent, while for rural households it increased by 12 per cent. Expenditure on Gas rose by 97 per cent and on Oil by 110 per cent (86 per cent in urban and 153 per cent in rural areas), while expenditures on coal, turf and LPG fell substantially. These patterns resulted from the increased prevalence of central heating, the growth of the natural gas industry and disapproval of "dirty" fuels. In 1987 half of all houses possessed full central heating and by 1994 that had increased to over two-thirds. However, this is certainly not the saturation level and the scope for further increase is evident from the 87 per cent possession rate in Northern Ireland dwellings in 1996.

This increase in central heating was greater for rural than for urban households (a catching up process) and this, along with the unavailability of piped gas in rural areas, explains the huge increase in rural oil demand. In urban households new central heating installations (and switches from solid fuel systems, which declined substantially in number) were split between gas and oil systems. In 1987, 5.4 per cent of households had gas fuelled central heating, while 13.3 per cent had an oil based system and by 1994 the corresponding figures were 21.1 per cent and 24.6 per cent respectively. The relatively greater increase for gas reflects a shift in the income status of the typical gas connected household. In 1987 the average income of gas connected households was lower than the average for households without connection, but in the 1994-95 survey the situation was reversed. The importance of the legislative restrictions on smoky fuels in urban areas can be seen from the facts that coal expenditure declined between these years by 39 per cent in urban, compared with 14 per cent in rural areas, while turf, because briquettes had been exempted from the legislation, declined by only 5 per cent in urban, compared with 15 per cent in rural areas. There was another "catching up" process of rural to urban as regards possession of electrically powered consumer durables and this was reflected in the relative increases in electricity expenditures – up 29 per cent for rural as compared with 3 per cent for urban households. (The free electricity allowance difficulties are ignored here, because they should largely cancel out of a comparison of successive rounds of the Household Budget Survey).

In spite of the increases between 1987 and 1994, overall levels of possession of central heating and of some consumer durables were still, as mentioned earlier, well short of saturation in the latter year. This, in conjunction with the high level of new household formation of recent years, which can be expected to continue for the years immediately ahead, suggests that the 1994-95 elasticity picture remains appropriate. Of course, if saturation approaches, the rate of new household formation will become the key determinant of the household sector's demands for oil, gas and electricity. The balance between future demand for oil and gas will depend, not only on relative price, but on household location and availability of gas connection.

Frequency of connection was related to type of housing in the 1994-95 survey. The higher frequencies occurred for Semi-detached (+Terraced) houses (32 per cent) and for apartment blocks (20 per cent). For houses built between 1918 and 1970, the incidence of gas connection exceeded a third. This fell to about 15 per cent for subsequent house construction up to 1985, but increased again to 24 per cent for houses built between then and the survey. Gas connected houses had a higher proportion of central heating (84 per cent) than had houses without gas connection (68 per cent). In the former, the system of central heating was predominantly (91 per cent) gas, while in the latter, oil fuelled systems were most frequent (50 per cent). However, since only a minority of houses were gas connected (26.3 per cent of urban or 17.9 per cent of all), oil based systems were more frequent (38 per cent) than gas fuelled systems (29 per cent) in urban areas.

Frequency of central heating was strongly related to type of housing. Of detached and semi-detached houses, 77 per cent and 72 per cent possessed central heating, as did 50 per cent of households living in large apartment blocks. For households living in small apartment blocks the percentage fell to 27 per cent and was lower still for bed-sitters and other accommodation. Oil was by far the most frequent heating fuel in detached houses (rural are included, of course), while gas was slightly more frequent than oil in semi-detached houses (33 per cent as compared to 31 per cent). Only in apartments was electric central heating relatively frequent.

It was the commonest system (50 per cent) for households living in small apartment blocks and the second most frequent for households living in large apartment blocks (33 per cent), or converted apartments (25 per cent), following oil systems in both cases (with 37 per cent and 41 per cent respectively). As might be expected, older houses had lower possession of central heating, while about 80 per cent of dwellings dating from 1960 to 1984 now have it. Since 1986, few dwellings have been constructed without it.

Although possession of central heating has become more prevalent in all social classes, it is still income related. There is over 90 per cent possession in the "higher" social groups such as "higher professional" and "self employed", falling to around 50 per cent at the "lower" end for such as unskilled manual. Perhaps more interestingly, the higher social groups favour oil or gas – the clean, convenient, fuels. The frequencies of these systems fall and backboiler and other systems become more common with lower social group.

Average energy expenditure by rural households exceeded that for urban households, although rural incomes were somewhat lower and the "catching up" as regards central heating and possession of electrically powered consumer durables had not quite achieved equality. The explanation does not seem to lie with differences in the fuel mix, although this did vary considerably between urban and rural because of the restrictions on smoky fuels in the former and the unavailability of gas in the latter. The greater frequency of older houses in rural areas and the far greater frequency of detached houses seems to increase the expense of home heating, although there may be other possible explanations such as housing utilisation, if rural homes are more likely to be occupied during the day.

Quantification of the relationship between household expenditures on fuels and income, which is necessary for certain purposes (forecasting , for example) was achieved by estimating Engel curves and income elasticities. Electricity is the most important fuel, but in 1994 over 18 per cent of Irish households possessed a free electricity allowance and this created complications in using the Household Budget Survey data for estimation. Ignoring the allowances would have biased the income elasticity estimate upwards and have distorted comparisons between the results for urban and rural households. The imputation procedure, as justified in Conniffe (2000), permitted derivation of useable income elasticities. For the State as a whole, the income elasticity – the percentage increase in electricity expenditure, given a one per cent increase in income – was estimated to be .35. This elasticity and all others given here are calculated at the mean. Because of substantial economies of household scale in electricity utilisation, the household size effect (given fixed income) was small and not statistically significantly different from zero. For this reason, too, the income elasticity averaged over household size equalled the income elasticity at fixed household size. For most fuels these will differ and the former is probably best for short run prediction of response to income, while the latter is better if investigating separate effects of income and household size changes on fuel expenditure.

The income elasticities of gas and oil were relatively high, the whole State values being .75 and 1.05 respectively. Energy is usually thought of as a necessity, which normally implies a low, but positive, income elasticity, as in the case of electricity. The reason for the high figures for gas and oil, with the latter being technically a "luxury", is that possession of a clean system of central heating is very definitely an aspiration of every household as income increases. Gas is largely a central heating fuel and oil is entirely so. The income elasticities (at fixed household size) of gas and oil were, .68 and 1.09 respectively. The household size elasticity (at fixed income) is significantly negative (-.28) for oil, which is not surprising. Larger household size usually means more children. Children imply certain commitments and divert expenditures towards necessities. So although a childless couple with a certain income could afford to install central heating, parents with children and the same income may be unable to afford to.

For the fuels coal, turf and LPG, expenditures fall with higher incomes, so that the income elasticities are all negative. The whole State income elasticities were -.29, -.30 and -.32. For coal the income elasticity (at fixed household size) was -.56, although this was a pooled average over considerably different urban (-.69) and rural (-.1). The legal restrictions on smoky coal in urban areas may be a factor in the difference. Lower income households may have stayed with coal, by substituting the more expensive smokeless coal (and claiming the fuel allowance provided for the purpose), while higher income households switched to central heating. The urban household size elasticity (.76) is statistically significant and large, probably because households at fixed (lowish) incomes with children or other dependants will not be able to afford to install heating systems that use oil or gas and have to stay with smokeless coal. For turf, income elasticities (at fixed size) are negative (-.43 for the state) while those for size are positive (.25 for the State) and similar interpretations apply. For LPG, the least important fuel, elasticities are again negative for income (-.39) and positive for size (.16), although the latter was not statistically significant. Indeed, for the rural sector neither income nor household size effects were significant.

From the elasticities for fuels, those for overall energy expenditure were deduced by weighting by fuel shares. They are preferable to the estimates that were earlier obtained by relating total energy expenditure to income, because the "free electricity effect" would have introduced bias, since electricity is the most important fuel in expenditure terms. The income elasticities were .25, .29 and .25 for the State, Urban and Rural respectively. The corresponding income elasticities at fixed household size were .19, .23 and .25 and for size at fixed income were .15, .18 and .01.

Electricity elasticities previously estimated from earlier rounds of the Household Budget Survey probably contain biases due to failure to take proper account of the free electricity scheme, but, of course, the relevant authors did not have access to household level survey data. To a lesser extent, the overall energy elasticities may have been similarly affected. Some anomalies in the historical record of estimates may be explicable on these grounds. As regards estimation from future rounds of the HBS, it is conceivable that demographic change, alterations to free electricity eligibility conditions and especially an increase in the size of allowance could worsen the bias problem and even invalidate some of the assumptions on which the corrective approach derived in Conniffe (2000) was based.

## 9.2 Implications for Energy Policy

As was outlined in the introductory chapter, energy policy in Ireland has varied over time and has seemed to have largely been determined by the predominant problem of the moment. Energy policy could be focused on any of several not entirely compatible objectives or, perhaps more realistically, could seek a balance between them. The objectives could include: minimisation of national energy costs; maintaining maximum security of supply; minimising negative externalities, such as damage to the environment; safeguarding household welfare and perhaps even maintaining employment in regions very dependent on energy utilities.

Currently the environmental aspect seems dominant, in view of the general scientific concern that carbon dioxide emissions are causing global warming and the specifications of the Kyoto agreement, to which the EU is party. Energy used in homes is, of course, only one component of national energy use and hence of emissions. As was discussed in the introductory chapter, other economic sectors consume more energy and, indeed, Conniffe *et al.* (1997) have shown that, on present trends, the greatest increase in consumption will be attributable to more private motoring and a greater stock of cars. However, the household sector contribution to emissions and its potential for increase is important. The Housing Executive (1998) paper quoted 1996 UK figures of average annual carbon dioxide emissions from dwellings. In Great Britain emissions averaged 7.5 tonnes per dwelling, while in Northern Ireland the corresponding average was 16.7 tonnes. The reason the figure for Northern Ireland was more than twice as large was largely because British dwellings were far more likely to have access to natural gas, which has a much lower carbon intensity than oil or solid fuels. With the somewhat lower proportion (at least in 1994-95) of centrally heated houses in the Republic and more access to natural gas than in Northern Ireland, although less than in Britain, the average annual carbon dioxide emissions from dwellings here is probably in between these figures. Multiplied up by the 1.05 households for 1994-95, the total is not at all negligible.

Turning to the potential for increase, the recent Medium-Term Review of the Irish economy by Duffy, Fitz Gerald, Kearney and Smyth (1999) forecasts the number of households increasing by 45,000 per year for a decade and also predicts a doubling of disposable income over the same period. Because of the low income elasticity, a doubling of a household's income would imply only a 25 per cent increase in its energy consumption. However, taken with the increase in number of households, the sector's energy use would grow by around 80 per cent. It may well be plausible that future household size will be smaller, on average, than currently, but hardly by enough to make much difference, given the small size elasticity found earlier. The 80 per cent increase in energy consumption need not translate into a corresponding increase in emissions. All fuels, except for electricity, contribute directly to carbon dioxide emissions with the fossil fuels – oil, coal and turf – having the higher concentrations and, as the UK emissions figures show, this can make a big difference. However, except for oil, consumption of fossil fuels has been shown to decline with income and also, as has been mentioned, almost all newly constructed dwellings embody central heating, predominantly gas or oil based systems. So as regards increased direct contributions to carbon dioxide emissions, attention can effectively be confined to oil and gas. Actually, the validity of these statements could depend on the relative prices of fuels remaining constant, as they were within the Household Budget Survey data, and the subject of price changes will be returned to.

Gas, with its lower carbon dioxide emissions, is an alternative central heating fuel when gas connection is available. For households within areas served by the existing gas grid, availability may still depend on the type of building containing, or constituting, the dwelling. In apartment blocks, as has been pointed out, not only oil, but also electrical, central heating systems were more frequent in 1994-95 than gas systems. There may be several reasons, including the marketing strategy of the gas industry, but building regulations constraining delivery of gas (or oil) supplies to apartments and requiring separate boiler houses must be a factor. Otherwise, it is hard to see why electric central heating is the most frequent system in small apartment blocks, while it is rare in detached, semi-detached or terraced houses.

More importantly, availability depends on spatial location. Access to the gas grid is not available in areas currently considered rural, but it is probably true to suppose that most new dwelling construction will occur as new estates of houses or apartments. If these estates are close to the existing gas grid, as they will be if they are extensions to current urban areas, connection should not be a difficulty. The exploitation of the new gas field off County Mayo will probably add considerably to the grid and make piped gas available to some towns currently without access. The potential Northern Ireland market, as described in Section 3.5, is relevant in this regard and might make connections to some towns in the Republic's border regions economically feasible. Even in the case of a town, distant from existing grids, a profit motivated gas utility could be expected to invest in the necessary grid extension if the potential sales volume justified it. If emissions control was to be the totally paramount policy objective, direct State interventions might be warranted in some circumstances. Even so, subsidising grid extensions in cases where the industry would not otherwise undertake them, would not make sense. LPG also has relatively low carbon dioxide emissions and subsidies or other interventions could counter the tendency, in the previous section, for it to be substituted by oil as incomes increase. Where safety considerations and constructional constraints, not lack of gas main proximity, is the barrier to connection, regulating for larger apartment blocks, or grant-aiding provision of regulation compliant gas heating in smaller blocks might be possibilities. But all these interventions conflict with other policy objectives and perhaps State involvement in gas promotion should go no further than ensuring that the gas industry is efficient and competitive. The industry itself could then be expected to extend the grid to its economic optimum and to defend its own interests with the house/apartment construction industry.

Other State efforts might be more productively devoted to reducing emissions in the remaining oil using households through encouraging efficient energy use and conservation measures, such as insulation etc. Scott (1993) found that relatively few households were adopting reasonably straightforward conservation measures even though the resulting energy savings and consequent expenditure reductions would more than cover the costs of adoption. She attributed this market failure to inadequate provision of information. The 1996 Northern Ireland House Condition Survey reported a much more positive response there as regards adoption of conservation measures relevant to heating.

Turning to indirect contributions to emissions, household electricity use does not contribute to the problem directly, but the generation of that electricity will do so, with the volume of carbon dioxide greatest if the power stations employ fossil fuels. The electricity generation sector is obviously outside the scope of this report, but has been covered in Conniffe *et al.* (1997). All that can be considered here is the contribution the household sector makes to demand for electricity. This is substantial since it is the fuel on which household expenditure is greatest (over 40 per cent of household energy expenditure). Assuming new household formation at the rate already specified and a doubling of incomes, the income elasticity of .35 suggests an 95 per cent increased electricity demand. However, it has been stressed that the elasticity largely derives from increases in the stocks of electrically powered appliances and that saturation is conceivable. The 1994-95 situation was still well short of saturation, but stocks will have increased since then and a doubling of income over the next decade will probably leave very few households without all the current electrically powered household appliances well before

2010. So an estimate of an 80 per cent increase seems more plausible. But it might underestimate. Saturation may not be inevitable, because there must be some likelihood that new electricity powered appliances will be invented and marketed. Nor can it be known in advance how energy intensive they might be.

As regards achieving some mitigation of this increased electricity demand, State interventions to encourage appliance efficiency and conservation (perhaps especially for apartment dwellers employing electric central heating) may be worthwhile, although the issues raised by Scott remain pertinent. She included installation of low energy light bulbs among the measures she studied. Interestingly, the 1996 Northern Ireland Survey also found a relatively low level of adoption of this innovation. It may be worth mentioning that policy makers should be wary of extensions to the free electricity scheme and especially of increasing the number of free units, as this would increase electricity demand and may well not be a efficient approach to improving the welfare of the needy. Turning to the price of electricity, Conniffe *et al.* (1997) considered the strategy of switching fossil fuel powered electricity generation to gas powered and calculated this would increase electricity price by about 5 per cent. A price increase would decrease household consumption somewhat, but probably by very little. As was explained in the introductory chapter, price elasticities cannot be estimated from the Household Budget Survey, so there is no direct confirmation of this. However, since household electricity demand derives from possession of appliances, for most of which there is no substitute fuel, we can expect it to be quite price inelastic.

Discussing price marks an appropriate point to leave the emissions policy objective and briefly consider the implications of the Household Budget Survey results for the other objectives. The objective of minimisation of national energy costs has to be interpreted in the context of possible changes in world fuel prices and patterns of supply. This implies switching between fuels if relative prices change substantially. After the oil price hikes of 1974 and 1979, huge efforts were made to diversify away from oil, with active encouragement to burn coal and turf in the home, to use it for solid fuel central heating and for electricity generation. (Grants were even paid to install fireplaces and chimneys in houses constructed without them in the preceding cheap oil era.) The subsequent fall in oil prices and concern about polluted urban air changed all that again. It will be abundantly clear from the earlier chapters that the household sector has now become very dependent on gas, oil and electricity. If the emissions policy objective is truly the supreme priority, the dependency on gas will become ever greater through its direct use in households and for the generation of household electricity. In these circumstances, the consequences of a big gas price hike could be just as economically damaging as were the oil price increases in the past.

Similar comments apply to maintaining maximum security of supply, although further gas finds around the Irish coast might help in this regard. As regards household welfare, it is a quite tenable argument that providing income support where necessary and promoting efficiency and competition between the various fuel suppliers is the best strategy. The objective of maintenance of employment in some energy related areas (Bord Na Móna, for example), can have little value in itself in current Irish circumstances of labour shortages, although some such maintenance might follow from a wish to retain a diversity of energy sources. Here again the issue of the priorities of the objectives of minimising cost and security of supply arise. Much hangs on whether the specifications of the Kyoto agreement are to be taken as truly binding, or as already unattainable targets. Although it would be much easier to assess the implications of findings from the HBS (or any other source) for energy policy if priorities were clear, it cannot be the role of this paper to formulate such priorities.

# Appendix

## INSTRUMENTAL VARIABLES AND ANALYSIS OF MEANS OF GROUPS OF HOUSEHOLDS

The method of instrumental variables (or two stage least squares) was developed by various authors, including Geary (1949), to deal with the problem of an explanatory variable being endogenous, or subject to errors of measurement. The standard regression formulae are not appropriate under such circumstances. For the reasons mentioned in Chapter 4, total expenditure is a better measure of "true" or "long run" income than is recorded household income. However, employing it introduces an element of endogeneity, because the dependent variable (expenditure on energy) is then a direct component of the income measure.

The instrumental variables method requires "instruments" – variables related to total expenditure y, but unrelated to the dependent variable (here energy expenditure) except through y. In the simplest case of estimation of a linear regression

$$x = a + b\,y + e,$$

suppose one instrumental variable z is available. The IV estimator of b is

$$\frac{\sum (z_i - \bar{z})(x_i - \bar{x})}{\sum (z_i - \bar{z})(y_i - \bar{y})}.$$

The usual regression coefficient would result from taking z = y. The estimator can also be obtained by first regressing y on z to get a function of z that predicts y and then regressing x on this "predictor" of y and hence the term "two stage least squares". When several instrumental variables $z_1, z_2, \ldots$ are available, the predictor of y is obtained by initial regression of y on $z_1, z_2, \ldots$ For the HBS, the instrumental variables derive from the qualitative or categorical variables. Suppose, for example, a qualitative variable has r categories. These define r – 1 instrumental variable $z_1, z_2, \ldots z_{r-1}$, each of which is a binary (dummy) variable taking the values 0 or 1. Regressing income on such variables provides the predictor of income, which replaces income in the final step of the IV estimation procedure. The method seems complicated, but is actually much more easily performed than the account suggests.

Wald (1940) and Bartlett (1949) had suggested an intuitively plausible approach to the problem of estimating b in x = a + b y + e, when the explanatory variable y is subject to error. They divided observations into groups (keeping the number of groups small enough to ensure sizeable numbers of observations in each group) and then regressed the group means of x on the group means of y using weighted regression. The idea is that if the y values within group i (of size $n_i$, say) are actually uncertain, it is better to treat the data as if $n_i$ observations had been made at the point $x_i$, $y_i$. The resulting estimator for b is

$$\frac{\sum n_i(\bar{x}_i - \bar{x})(\bar{y}_i - \bar{y})}{\sum n_i(\bar{y}_i - \bar{y})^2},$$

which is easily computed. Now it can be shown by some rather tedious algebra that the IV estimator, when the instrumental variables are derived from categorical variables, is exactly the same as that obtained by defining groups by categories (or combinations of categories) and regressing group means on each other, weighted by group size. The more categories are simultaneously employed the larger the number of groups and the smaller the number of households in each group. Obviously the occurrence of a zero group size must be avoided (the analogue for categorical variables of avoiding multicollinearity with continuous variables), which would restrict the number of categorical variables employable (many combinations of categories being unlikely, such as high social class and low level of education).

However, there is a more important reason to keep group sizes quite large and so restrict the number of groups. The Central Statistics Office's interviewers spread the survey work over a year, recording detailed expenditures with one set of households for 14 consecutive days and then moving to the next set. So there can obviously be large seasonal effects (Christmas spending on food and drink, for example) that can distort comparisons between groups based on small numbers of households. It is true that for commodities where an individual household's purchases are infrequent but expensive (an electric cooker, say), the CSO seeks retrospective data from before the 14 day period, but seasonal effects can remain. For energy expenditure, the matter is clearly crucial, since heating and lighting requirements are greater in Winter. For electricity, for example, expenditure is measured in the HBS on the basis of the ESB's bill for the most recent two month billing period and the amount will obviously vary with the time of year households are interviewed.

The solution is to ensure that the group means are all based on a substantial number of households reasonably distributed across the seasons. The two sources of instrumental variables for the analyses in this report are a categorisation by deciles of gross household income (note this just uses reported income as a grouping factor) and the categorisation Social Group (from Headers 7 and 17 of the HBS respectively). This double classification would generate 99 instrumental variables, but some of the corresponding group means would be based on too few values, since a Social Group like "Higher Professional" will have few or no households in the low income groups. On the other hand the Social Group "Farmers" contains a wide range of income groups. Obviously, when working with subsets of the survey data (urban only, say, or particular household compositions, as in Section 5.3), the number of groups has to be reduced to maintain group size. Standard errors of coefficients show corresponding increases.

Since the mechanics of the IV estimation are identical to weighted regression of group means, so far as derivation of coefficients, standard errors and t values are concerned, the analysis can be performed by a standard regression package. But many of the conventional goodness of fit and diagnostic test criteria usually produced are either not applicable or require different interpretation. Some such points have been noted in the report.

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