"THE DEMAND FOR ELECTRICITY IN GREECE: 1961 - 1975 AN EMPIRICAL INVESTIGATION"

by

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ABSTRACT

This study attempts to provide quantitative estimates of the influence of changes in economic variables (relative prices and activity indicators) on electricity demand in Greece over the period 1961 - 1975.

The fact that electricity is not a product yielding direct satisfaction but it is demanded as a fuel input into activities that do provide utility, and which use a capital stock of some durability, creates the need for a distinction between demand in the short-run and demand in the long-run. Moreover, total electricity demand is disaggregated into demand by the household, commercial and industrial sectors. This disaggregation rests upon the assumption that the response of different sectors to changes in the economic environment is unlikely to be the same.

The quantitative estimates suggest that in general short-run demand appears to be price and income inelastic for the household and commercial sectors, whereas for the industrial sector the evidence suggests a price elasticity very close to unity and an activity indicator (Index of Industrial Production) elasticity greater than unity. Long-run demand appears to be inelastic with respect to price changes only in the household sector. The activity indicators elasticities for all sectors are well above unity.

The long-run formulations permit the calculation of the speed with which actual demand adjusts to desired

demand. The estimates suggest that this speed is relatively fast in the case of residential demand and relatively slow in the case of industrial demand.

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Chapter 1

Introduction

1.1 The purpose of the study

The purpose of this study is the investigation of electricity demand in Greece. The analysis aims at the formulation, estimation and testing of models which explain variations in electricity demand over the period 1961 - 1975.

Such an analysis is thought to be necessary, because while electricity is an important energy form, it is a product for the generation of which considerable amounts of imported oil are needed[1]. The rapid increases in oil (and electricity) prices during the 1970s had considerable effects on the country's development and balance of payments. The question thus posed was whether price increases would be followed by a reconsideration of consumption patterns and, if not, the economy's ability to orientate itself towards alternative electricity generating sources. This would imply construction of additional power-generating stations using indigenous inputs such as water-power or lignite. However both problems are directly or indirectly associated with the question of responsiveness of demand to increasing prices and no empirical evidence was available on which relevant conclusions and actions could be based.

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[1] See table 1.1, chapter 1, p. 9.

On the other hand the problem of estimating the demand for electricity is conceptually difficult because electricity is a derived demand rather than a final demand; that is, electricity is demanded not for its own sake but because it can be combined with other inputs to produce satisfaction-yielding services. Since these services utilize a capital stock of some durability, one ought to distinguish between short and long-run demand for electricity. Moreover, since electricity is demanded by various economic sectors that are likely to react differently with respect to changes in the economic environment, it is useful to disaggregate total demand into demand by the household sector, the commercial sector and the industrial sector.

The development of the model necessarily progressed side by side with the collection and processing of the data, since the exact form of the model could only be determined when the limitations imposed by data availability were known; and yet the collection and processing of the data could not be completed until the requirements of the model were worked out.

Data constitutes a very important feature of this work since its largest part is unpublished time series covering the period from 1961 through 1975. Data referring to electricity consumption, the number of customers and the electricity tariffs for each of the three categories of customers were offered by the Public Power Corporation. To the best of our knowledge these data have not been used in published research before. Data referring to other economic and social factors on the other hand were obtained from official statistical sources (see Appendix 3, Data and Sources).

Because of the difficulty in estimating electricity demand models, a question is raised concerning the appropriate framework within which electricity demand should be examined. The point at issue here is whether an investigation of electricity demand should be carried out within the context of an overall energy market. The basic product for which consumers have a (specific) demand is "energy" and therefore it would seem appropriate that an examination of the demand for any fuel should involve an investigation in two stages, the first stage dealing with demand for energy as a whole and the second with the shares of the specific fuels (gas, oil, coal and electricity) in a broadly defined energy market. However as has been pointed out by Baxter and Rees "there is a practical problem which has to be met in this approach relating to measurement. In order to derive a statistic of total "energy", it is necessary to reduce each fuel to a common unit of account. Each of the fuels has a calorific value which could be used but this would ignore the fact that the separate fuels are more or less efficient converters into final usable energy and have varying conversion efficiences depending on their application"[1].

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1 Baxter and Rees, (1968), p. 278.

A number of procedures have been proposed as a way of overcoming this practical difficulty. According to the first, all fuels are converted into a "usable energy content" which is the maximum amount of energy that can be obtained through an ideal mechanical process. A second method involves the construction of a weighted value index based on the prevailing market prices and consumption of the fuels to be aggregated. Another procedure involves conversion of fuels into a common reference through the utilisation of their calorific values relative (mainly) to that of coal which is used as the reference fuel. In this way the demand for each fuel is expressed in terms of coal equivalent tons.

The difficulties associated with an overall energy statistic are due to the fact that the efficiency of fuels changes from application to application and from fuel to fuel. This idea, of using a total energy statistic as a framework within which to fit component fuels may therefore have doubtful validity.

An alternative approach, and the one adopted in this study, is to follow the Baxter and Rees methodology and treat electricity separately. As well as being a simpler and more direct approach, it also avoids the practical and conceptual disadvantages of the aggregate "energy" analysis.

It should be emphasised however that the developments that took place in the electricity market during the period we propose to investigate (1961 - 1975) may not be treated in complete isolation from an overall energy context. What is even more important is that the future developments in the electricity market should be seen within the overall energy problem as it appears in the country today, as well as the side effects that this is likely to create.
Because of these reasons a discussion concerning the overall energy market in Greece is provided in Appendix 1.

1.2 Electicity in Greece

Before any attempt is made towards analysing the supply and demand sides of the electricity market in Greece, some facts that played a decisive role in its development should be mentioned. Probably the most important of these facts is the establishment and subsequent expansion of the Public Power Corporation and its influence on the energy sector of the economy[1].

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1 See Apostolakis, G.E., (1963).

Before the Second World War (in 1939), electricity availability and production in most areas, with the exception of the Athens-Piraeus area, was in an almost primitive state. Electricity was produced by 349 small firms and distributed to approximately 400 cities and villages. The Athens-Piraeus area was served by a well established and organised enterprise - the British-owned Electricity Company of Athens and Piraeus. For the country as a whole, the per capita annual consumption of electricity was around 34 KWH, but once a distinction is made between the Athens-Piraeus area and the rest of the country the picture is different. To a 168 KWH per capita yearly consumption in the capital of the country there corresponded a 10 KWH per capita in the province.

Generation of electricity was carried out almost exclusively through thermal stations operating with liquid fuels. Seven percent of the electicity produced was generated by hydroelectric stations. The overall installed capacity of the existing stations was less than 400 GW.

The events of the Second World War made the situation even worse. A considerable number of electricity generating stations was destroyed and this multiplied the already existing energy and economic problems of the country[1].

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1 Farakos, G.K., (1964).

The importance of electricity and the dependence of the economy's growth on the likely solutions to energy problems were considerable. In the years immediately after the War, a "Greek Energy Program", financed by the USA through the "Marshall Plan", was put forward. The program, approved by the Organisation of Economic Co-operation and Development (OEEC), stressed the necessity for the establishment of a Company engaged fully in the generation, transmission and distribution of electrical energy in Greece.

In August 1950 the Public Power Corporation (here after PPC) was established operating under private law although it is an entirely publicly owned utility. The operation of the Corporation started in 1953 and the production of electricity sold to already existing utilities was set as an initial target. At the beginning the management of the Corporation was given to the American "Ebasco Services Inc." which undertook the task of accomplishing the first Greek energy program.

In 1954 the PPC aquired the publicly-owned utilities in Thessaloniki and the following year began supplying power to customers in previously unserviced areas. By the middle of 1955 the first energy program was completed and the Ebasco Services Inc. handed over the management of the Corporation to the Greek authorities. In the following years the Corporation acquired some 400 utility companies, with a total generating capacity of 223,000 KW

(132,500 KW in Athens-Piraeus and 90,500 KW in the province). The most important acquisition, namely that of the foreigh-owned Athens-Piraeus Electricity Company Ltd., which used to serve, as its name indicates, the country's largest metropolitan area, was made in 1961. At present, the entire Greek mainland and a few islands are served by the Corporation's interconnected grid, while other islands, accounting for less than 5 percent of the country's energy consumption, are served by local systems. PPC generates more than 98 percent of the electrical power produced in Greece the remainder being generated by a few industries for their own use. It is the country's largest industrial enterprise with total assets of the order of $ 2,330 million and revenues of about $ 419 million at the end of 1974. The main objectives of the Corporation may be summarised as follows:

1. To meet the country's constantly increasing electrical energy requirements resulting from its rapid industria-lisation;

2. To utilize in full all domestic sources of energy. To this end investigation of the lignite, hydraulic and other energy resources of the country are necessitated th-rough the implementation of a special program;

3. To supply electric power to all towns and villages of the country.

Nevertheless, despite the fact that the first and third objectives seem to have been met fairly succesfully, the same thing cannot be said for the second objective. Since 1960 the percentage of imported liquid fuels has been increasing rather than decreasing as table 1.1 shows:

TABLE 1.1

Primary Energy Inputs for Electricity Generation

(Percentage Distribution)

Energy Sources	Years		
	1960	1970	1975
Liquid Fuels	26	35	41
Solid Fuels (Lignite)	53	37	46
Waterpower	21	28	13
Total	100	100	100

Source: PPC, Division of Statistics

In 1974 the capacity of the operating stations of the interconnected system was 3.79 million KW. These stations may be classified into two main categories:

1. Thermal Stations, burning either local lignite or imported liquid fuels or both; and
2. Hydro Stations.

The situation in 1974 is shown in the following table 1.2:

TABLE 1.2

Hydro Stations	Capacity in MW		
	Sub-total	Total	Grand-total
Argas - Edessos - Louros	79.3		
Tavropos - Kastraki - Lanhon	520		
Kremasta - Polifiton	687		
Veria - Glafkos - Serres	4.1		
Total		1290.4	
Thermal Stations			
1. Burning local lignite		1170	
Ptolemays Group	920		
Megalopolis	250		
2. Burning imported Liquid Fuels		1105	
St. George Bay	480		
Alivery	150		
Lavrion	450		
Gas Turbine Station	25		
3. Burning either lignite or Liquid Fuels or both		230	
Alivery	230		
TOTAL			2505

Source: "The Hellenic Electric Power System", PPC,(1975), p. 7.

From the previous table it can be seen that, in 1974, the operating Thermal Stations accounted for 66 percent of the total capacity and the Hydro Stations for 34 percent. Before the establishment and operation of PPC the electric output was almost entirely thermal, 93 percent of it being generated by imported fuels and 7 percent by waterpower. In 1975 electrical energy generation reached the level of 15 billion KWH and in 1976, 16.3 billion KWH.

Before the establishment of PPC, the Athens-Piraeus area consumed 86 percent of the country's total electrical energy. This was so because most industrial units were concentrated in this area where electrical power was available. Since availability has been extended to all areas in Greece, large industial units have been established in provincial areas, consuming electricity amounting to 59.4 percent of the country's aggregate industrial consumption. In 1974 the total consumption of electricity in the Athens-Piraeus area was 36.1 percent of the total consumption in Greece. The following table (table 1.3) shows the consumption of electricity and the number of customers, by category of use in 1974.

TABLE 1.3

Categories of customers	Consumption of Electricity (GWH))[1]	Number of customers at the end of 1974 (persons)
Residential	3,002	2,835,000
Agricultural	207	46,000
Commercial	1,514	522,000
Industrial	7,601	109,000
Public Authorities	522	53,000

Source: "The Hellenic Power System", PPC, (1975), Athens.

The annual rate of increase in total consumption between 1960 and 1974 was 11.6 percent. The industrial consumption in Greece accounts for 59.2 percent of the total consumption while the net per capita consumption outside the Athens-Piraeus area increased from 16 KWH in 1952 to 1,600 KWH in 1974. Before 1950 only 7.1 percent of the towns and villages were connected to the electrical networks existing at that time. These networks provided electricity to 55.2 percent of the total population of the country. At the end of 1975 the towns and villages serviced amounted to 98.6 percent.

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1. 1 GWH = 10^6 KWH = 10^9 WH.

In Greece, as in other countries, a system of electricity tariffs is applicable. These tariffs are established on the basis of charging the customers serviced under the same conditions equally. Electricity tariffs are divided into three general categories corresponding to High, Medium and Low Voltage customers.

The favourable tariff policy towards vital economic sectors (for example in agriculture) was an indirect encouragement for the introduction of modern and more electricity intensive techniques and equipment which in turn increased electricity demand. As a result, in 1975 for instance, 220 million KWH were consumed in 50,846 irrigated establishments (2.48 million acres) of the agricultural sector. The industrial sector, on the other hand, consumed 8 billion KWH, that is 57.8 percent of total consumption. The remaining 42.2 percent was consumed by all other economic sectors.

The above analysis concentrated on an examination of the electricity market in very general terms. But given that total electricity demand is to be disaggregated into three component parts (household, commercial and industrial demand), the identification of the relevant economic factors to be included in the formulated relationships approximating the behaviour of each sector, will be examined after a very brief discription of the developments in each market, and a brief review of similar studies (chapter 2).

1.3 Electricity Markets

a. Residential Electricity Market

During the last fifteen years residential electricity sales in Greece have increased at an average rate of over 11 percent per year. From 1960 to 1975 the population increased by about 8.6 percent while residential electricity consumption rose by more than 490 percent. It is estimated that during this period about two fifths of the growth in residential electricity use was attributable to rising consumption per household, and about three fifths was due to the increase in the number of households served. Nevertheless, on the average the typical Greek household which used less than 200 KWH of electricity in 1960 consumed over 1500 KWH in 1975.

The main economic causes of this considerable increase in residential electricity demand are: first, the vast growth in the rate of electrification, from 7.1 percent in 1954 to almost 85 percent at the end of 1975. Second, the widespread introduction of electricity using appliances such as refrigerators television sets, washing machines and so on. At the same time a gradual shift to electricity from other fuels (for example in space heating, water heating and cooking) played an equally important role. On the other hand the continuous increase in personal income combined with the relatively low electricity prices charged helped the expansion of the market over the same period.

b. Industrial Electricity Market

During the period under consideration industrial electricity consumption has grown at an annual rate of nearly 9 percent. At present, while manufactruring industries account for only 20 percent of total earnings in the Greek economy, they account for about 58 percent of total electricity power consumption. On the other hand only a very small proportion, 2 percent, of total industrial consumption is self-generated, the vast amount of electricity being supplied by the PPC, either through individual contracts with the Corporation (for example ESSO PAPPAS, LARKO), in which case the price of electricity is fixed in advance, or through high and medium voltage tariffs applied to groups of industrial customers.

In an attempt to analyse the factors affecting electricity demand by the industrial sector certain limitations are imposed due to some peculiarities of the structure of Greek industry[1]. The latter may be summarised as follows:

(A) The Size of Industrial Establishments: In Greece there are a great number of small establishments employing, in 1973, less than 10 persons and making up 95 percent of total industrial establishments. In fact it is only the remaining 5 percent of industrial units employing more than 10 persons that could be considered "industrial". This percentage absorbs 50 percent of the total

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1 Germidis, D.A., and Negreponti-Delivanis, M., (1975).

labour force and pays over 75 percent of the total wage bill. The small size and moreover the "family" character of the existing units, sets limitations to data referring to output produced, consumption of electricity or other fuels, wage rates and to other economic variables. On the other hand, since 1970 data referring to small scale industry, (that is industries employing 10 persons or less) which in fact constitute, as it was said above, 95 percent of the industrial sector of the country, has not been recorded.

(B) The second disadvantage of the industrial structure refers to the Type of the Products Manufactured, a picture of which may be given in the following table:

TABLE 1.4

Breakdown of Industrial Establishments by Activity

(percentage)

Industries	Industrial Establishments				
Total Manufacturing Industry	1963	1965	1967	1969	1970
1. Consumer goods	74.12	73.07	72.99	71.20	69.85
2. Intermediate goods	7.24	7.68	7.79	8.09	7.95
3. Capital goods	18.64	19.25	19.22	20.71	22.20

Source: "Industrial Censuses of Greece", 1960 and 1975.

Table 1.4 shows that consumer goods industries[1] predominate since they constitute over 70 percent of all industrial establishments. However, this percentage seems to have decreased compared with that of the capital goods industries[3]. The percentage of the intermediate goods industries[2], on the other hand, remained remarkably stable, around 7 percent, throughout the period. Electricity is a very important production input especially for the capital goods industries; hence increases in output produced by the sector or establishment of new units, bring about considerable increases of electricity

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1 Consumer goods Industries	1. Manufacturing of food, beverages and Tobacco
	2. Textile Industries
	3. Manufacture of Footwear, Wearing Apparel and Leather
	4. Manufacture of Wood and Furniture
	5. Manufacture of Rubber and Miscellaneous Prod.
	6. Metal Products (except machinery)
2 Intermediate goods Industries	1. Manufacture of Paper and Paper Products
	2. Manufacture of Chemicals (oils, petroleum and coal products)
3 Capital goods Industries	1. Manufacture of non-metallic Mineral Prod.
	2. Basic Metal Industries
	3. Manufacture of Electrical Machinery
	4. Manufacture of Transport Equipment

The above classification follows that adopted by Koutsoumaris, G., (1963).

demand. Moreover in recent years, and especially during the sixties, the composition of industrial output has altered. The establishment of units producing goods requiring large amounts of electricity (electricity intensive industries such as aluminium industry and so on) led to a significant increase in electricity consumption from 954 MWH in 1961 to almost 3300 MWH in 1975.
Technological improvements in the production process played an important role but the contribution of new technologies is something very difficult to quantify. The dependence of electricity demand by the industrial sector on such factors, as well as the lack of detailed information regarding amounts of electricity used by specific industries and output produced, limits the choice of the variables to be included in the analysis and possibly the estimates that are reported in the relevant section (chapter 4) The latter should be interpreted with these important limitations in mind.

c. Commercial Electricity Market

Although the term "commercial" is used to describe the third important component of electricity demand in Greece, this sector includes the demands of widely differing types of users. Commercial electricity consumption includes the demand of the following sectors: wholesale and retail trade, finance, real estate, insurance, services (hotels, restaurants, business consulting firms, hospitals and others) and construction. It also includes the demand by four smaller sectors that is agricultural, interdepartmental, governmental and railroads. None of these four sub-categories are significant users of electricity. Together they consumed only about 5.67 percent of total electricity demand in 1974.

The available information indicates that commercial electricity demand grew by an average annual rate of 11.2 percent between 1961 and 1975. Its percentage growth was greater than that of total demand (10.8 percent). The major causes of this expansion were:

1. The establishment and rapid development of a considerable number of commercial units from 125 thousand in 1958 to 162 thousand in 1969[1]. This expansion was spread all over the country in large metropolitan centres such as Thessaloniki, Patras, Heraklion, Kavala and others.

2. The increase in Gross National Income which rose at an average annual rate of 7.5 percent during the period under consideration; and

3. The enormous increase in tourism which contributed to the creation of complementary commercial activities such as construction of large hotel units, restaurants and shops.

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1 Statistical Yearbook of Greece (1976), table XIII:17, p. 318.

Chapter 2

Review of the Literature

2.1 Introduction

In this chapter we provide a summary of the existing literature on electricity demand. The studies reviewed here by no means exhaust the literature. Most of the studies that have been left out, although of considerable potential (the analyses by Halvorsen[1] or Lyman[2] for instance are representative examples) are based on highly refined data or exhaustive market surveys. However, they are of little help for situations where vital information (for example information on stock of electric appliances) is not available as in the case of Greece. Hence we limit ourselves to a review of models that may provide a framework for an investigation based on comparable data requirements.

The absence of relevant empirical work referring to Greece, which restricts the review to a consideration of international studies, appears to be at the same time an advantage and a disadvantage. It is an advantage because it gives the study an element of originality and a disadvantage because there are no studies to compare our results with or to draw useful suggestions from.

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1 Halvorsen, R., (1973).

2 Lyman, R.A., (1973).

2.2 Studies Reviewed

Houthakker's work focuses on residential electricity consumption in the United Kingdom using cross-section observations on 42 provincial towns for 1937 to 1938[1]. In his model the appliance stock is an exogenous variable and he also introduces lagged values of price of electricity and gas. The demand equation is of the following form:

$$\text{Log}x = a_1 + a_2\log M + a_3\log p_{-2} + a_4\log g_{-2} + a_5\log h + u$$

where x is average annual electricity consumption per customer with a domestic two-part tariff; M is average money income per household with a domestic two-part tariff; p is marginal price of electricity on domestic two-part tariff; g is marginal price of gas on domestic tariffs; h is average installed load, in KW per customer of cookers, water-heaters and wash-boilers bought on hire purchase. The values of p and g are lagged two years.

As Houthakker was only considering two-part tariffs, on which the same marginal rate applied to all customers in a given town irrespective of their consumption, it was appropriate to use this marginal rate as the electricity price variable. By a similar argument the marginal rate was chosen for the gas price. This required more data than the usually published figures since these give average prices. As the marginal rate was in the short-run

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1 Houthakker, H.S., (1951).

independent of the quantity demanded there was no need to introduce a function defining the tariff to obtain consistent estimators. No long-run supply function was included on the argument that, in the cross-section, supply was independent of the variables included in the equation. The results, are shown in the following table:

Parameter	a_2	a_3	a_4	a_5
Estimate	1.166	-0.893	0.211	0.177
Standard error	(.088)	(.191)	(.117)	(.034)
R^2	0.87			

The values of p_{t-4}, p_t and g_t were also considered but the 2-year lags were found to give the best results. In other words the price variables were selected on the basis of trial and error process. As to the interpretation of his elasticity findings Houthakker does not comment on whether they refer to the short or the long-run. The important distinction between short-run and long-run demand was first made by Fisher and Kaysen in their pioneering study. According to their explanation (see below) the interpretation of estimates of models like the one proposed by Houthakker depend on the relationship between the appliance ownership variable and the remaining variables in the equation. As it will become clear when the study by Fisher and Kaysen is presented, the price and income elasticities (found above) may be interpreted as short-run ones indicating the effect on the utilisation of a constant appliance stock. The cross-elasticity with respect to the price of gas is possibly low, given that in the short-run substitution is possible only for those consumers who have both gas and electrical appliances.

The work by Fisher and Kaysen[1] is an early and possibly the most quoted study in the field of electricity demand. In this work an approach is followed, the main feature of which is the distinction between short-run and long-run demand by households.

Short-run demand is viewed as the analysis of factors that determine variations in the rate of utilisation of the existing stock of electricity consuming capital goods. The basic short-run demand equation is:

$$LnD_t = c + a\ln P_t + b\ln Y_t + \ln W_t^* \qquad (1)$$

where

D_t is the total household electricity demand in KWH

P_t and Y_t are the average price of electricity per KWH and per capita personal income respectively, expressed in real terms.

W_t^* is the average stock of electrical appliances (white goods) in period t expressed in the amount of KWH that the existing stock may potentially draw.

The low quality of the data relating to the stock of "white goods" leads to a reformulation of the short-run model in such a way as to eliminate W_t^* from equation (1). This is achieved on the basis of the assumption that the growth

1 Fisher, F.M., and Kaysen, C.A., (1962).

in W^* over time is exponential at a constant rate γ, that is:

$$W^*_t = W^*_o \cdot e^{\gamma t} \qquad (2)$$

Now, taking logarithms of both sides of (2) and substituting into (1) we get:

$$\ln D_t = c + a\ln P_t + b\ln Y_t + \ln W^*_o + \gamma t \qquad (3)$$

which upon taking first differences becomes:

$$\Delta \ln D_t = \gamma + a\Delta \ln P_t + b\Delta \ln Y_t \qquad (4)$$

With the additions of the disturbance term this is the model which is finally estimated. Note that the assumption represented by equation (2) produces an estimating equation whose constant term is equal to the hypothesised appliance stock growth rate. Using the states as the smallest observation unit on which data on D_t, P_t and Y_t exist, Fisher and Kaysen estimate their model of each of the 47 states over the period 1946 - 1957. Their results indicate overall that price and income were not significant in the demand relationship and moreover they predicted that the significance of price of electricity would decrease and that of income would increase in the future.

In the long-run the demand for electricity is identified with the choice of the size of the capital stock. Here the authors are interested in the question of the influence of the price of electricity and of the price of gas on the demand for major appliances, but other economic, social and demographic variables are also considered as explaining variations in the demand for appliances.

The long-run model, described as a "disease" model[1] of the growth of appliances stocks has as follows:

$$\Delta \ln W_{it} = A_i + n_{i1} \Delta \ln Y_t^E + n_{i2} \ln Y_t + n_{i3} E_{it} + n_{i4} \ln G_{it} + $$
$$+ n_{i5} \Delta \ln H_t + n_{i6} \Delta \ln F_t + n_{i7} \ln M_t + n_{i8} \ln P_t^E + $$
$$+ n_{i9} \ln Y_{it} + n_{i10} \ln V_t^E + u_{it} \qquad (5)$$

where:

W_{it} is the stock of ith electricity using good ("white good")

Y_t^E is a weighted average of lagged values of per capita income Y_t

Y_t is current per capita income

E_{it} is the price of the ith electricity using good

G_{it} is the price of gas using substitute for ith electricity using good.

H_t is the number of electricity customers

F_t is population

M_t is the number of marriages

P_t^E is three year moving average of electricity prices (a proxy for expected real price)

V_t^E is three year moving average of gas prices

Y_{it} is the average kilowatt hour consumption of a new unit of ith electrical appliance.

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1 "the possession of a unit of the given appliance is considered as the state of having a contagious disease. How many people have the disease at any given time is considered to depend on how many people had it before, how many people there are who are not immune, and on various other factors all affecting susceptibility". Fisher and Kaysen, (1962), p. 80.

The model is estimated for 1946 -1949 and for 1951 - 1957. The number of washing machines, refrigerators, ironing machines and electric ranges are the white goods used in turn as dependent variables.

On the basis of the estimates obtained, Fisher and Kaysen concluded that the price of electricity as well as the price of appliances do not have substantial effects on the stock of appliances. The major determinants of appliances stock were found to be changes in long-run incomes, in population and in the number of wired households per capita. These are precisely the variables whose first differences have been included in the right-hand side of the demand equation (5). The dependent variable also is in first difference of logarithms. All the other dependent variables are not in the form of first differences but in single period levels. This is apparently the cause of their insignificance in the estimated equation (5).

In the final part of their analysis an investigation of the industrial demand for electricity is discussed. They are considering two different possibilities: (a) when technology is constant and (b) the possibility of technological change. In the first place electricity is assumed as an input in the production process having two components: one fixed part consisting of lighting, heating ect. and one proportional part varying directly with output. Data were used for 10 different industry groups for the estimation of the model:

$$D_{It} = K.\, X_{It}^{b}.\, P_{It}^{a} + V_{It}$$

where D_{It} is total electricity demand used by the I indust-

rial group;

X_{It} is the total output produced by the I industrial group;

P_{It} is the real price of electricity to the group;

V_{It} is a random disturbance term.

The model was used in logarithmic form to obtain least-squares estimates, output being measured in terms of value added by manufacture.

The results obtained indicated a significant negative price effect in six of the ten industry groups and non-significant price effect in two more.

Turning now to the technological change question their aim was to investigate whether there was any change in magnitude and direction in the electric input coefficient for different industries. Lack of adequate data limited this investigation of change to an analysis of the electricity input coefficients for different industries in 1947 and 1956. Nevertheless they concluded that "technological change probably acted neutrally or increased the importance of electricity - the quantity of electricity consumed per unit of output - in this period"[1].

The argument that may be raised regarding Fisher and Kaysen's long-run conclusions is that these are based mainly upon an examination of a very limited range of electrical appliances which have no adequate substitutes and which

1 Fisher and Kaysen, (1962), p. 8.

account for only a small fraction of the total potential electricity requirement. Exclusive reliance on statewide averages on the other hand raises questions of aggregation in cases where state and market boundaries do not coincide, since intermarket variations in price and quantity may thus be obscured. Another point is that although Fisher and Kaysen's analysis identifies an association among population, income and electricity sales, it is inadequate in defining the all-important price - quantity relationship which, nevertheless, is stressed in their analysis. Without any doubt, however, their work was a pioneering one in the field of electricity demand; and not only did it stimulate interest on the subject but paved the path for subsequent and more sophisticated work.

Mount, Tyrell and Chapman[1] extended the investigation in two directions. Time - wise by considering available information up to 1970 (pooled time series and cross-section data) and sector - wise by analysing variations in electricity demand by the commercial sector as well. Setting as their objective the estimation of price elasticity for the period 1947-1970, they carry out the analysis in terms of the following models:

1. <u>Constant Elasticity Model</u> (for a particular year and state):

$$Q_{it} = A.\, Q_{it-1}^{\lambda} \cdot U_{1it}^{\beta_1} \cdots\cdots U_{Nit}^{\beta_N} \qquad (6)$$

1 T.D. Mount, T.J. Tyrell and L.D. Chapman, (1973).

where:

i is the ith state, t is the tth year,

Q is the quantity of electricity demanded,

U_N is the level of the Nth causal factor, and

A, , $\beta_1, \ldots, \beta_N$ are unknown parameters.

The short-run elasticity for the Nth factor is β_N and the long-run elasticity is $\beta_N/(1-\lambda)$. The value of λ must lie between 0 and 1 and $(1-\lambda)$ is the proportion of the demand response that is completed in the first year. Hence if λ is close to 0 the demand adjusts quickly in the causal factors; if λ is close to 1 the demand adjusts slowly.

2. <u>Variable Elasticity Model A:</u>

$$Q_{it} = A.\ Q_{it-1}^{\lambda} \cdot U_{1it}^{\beta_1} \cdots\cdots U_{Nit}^{\beta_N} \cdot e^{\gamma_1/U_{1it}} \cdots\cdots e^{\gamma_N/U_{Nit}}$$

where e is the base of natural logarithms and $\gamma_1, \ldots, \gamma_N$ are additional unknown parameters. The interpretation of λ is the same as in equation (6), but the short-run elasticity of the Nth factor is now $\left[\beta_N - (\gamma_N/U_N)\right]$ and the long-run elasticity $\left[\beta_N - (\gamma_N/U_N)/(1-\lambda)\right]$.

3. <u>Variable elasticity Model B:</u>

$$Q_{it} = A.\ e^{\delta_0/D_{it}} \cdot Q_{it-1} \cdot U_{1it}^{\beta_1 + \frac{\delta_1}{D_{1t}}} \cdots\cdots U_{Nit}^{\beta_N + \frac{\delta_N}{D_{Nt}}} \cdot e^{\gamma_1/U_{1it}} \cdots\cdots e^{\gamma_N/U_{Nit}} + u_{it}$$

where D is the level of the shift variable and $\delta_0, \delta_1, \ldots, \delta_N$ are additional unknown parameters. Under this specification the short-run elasticity for the Nth factor is $\left[\beta_N - (\gamma_N/U_N) + (\delta_N/D)\right]$ and the long-run elasticity is $\left[\beta_N + \left[(\gamma_N/U_N) - (\delta_N/D)\right] \Big/ (1-\lambda)\right]$.

The independent variables considered by the authors are population, income per capita, average price of electricity, average price of gas (lagged one year) and price of appliances (also lagged one year). One "shift" variable is employed, namely, the mean January temperature, which varies accross states or regions, but not over time. The model is estimated for the electricity consumption of each of the three classes of customers - residential, commercial and industrial. The following table gives a summary of their estimated elasticities:

	Estimated Elasticities[1]					
	Residential		Commercial		Industrial	
	S.R	L.R	S.R	L.R	S.R	L.R
Population	0.12	0.99	0.13	1.03	0.12	1.01
Income	0.02	0.20	0.11	0.86	0.06	0.51
Price of electricity	-0.14	-1.20	-0.17	-1.36	-0.22	-1.82
Price of gas	0.02	0.19	0.01	0.06	0.00	0.00
Price of appliances	-0.05	-0.42	-	-	-	-

Source: Mount, Chapman and Tyrrell, tables 3 and B-1.

As the table indicates electricity demand appears as

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1 Mean level for all states calculated at 1971 values of independent variables.

price elastic in the long-run but inelastic with respect to income, approaching to zero as income increases. Population exhibits approximately unit long-run elasticity for all classes of customers and the elasticities for both the prices of complements and substitutes of electricity goods are found to be less than 1. The inelasticity of income is probably due to the use of both income and population as exogenous variables in the demand equations, since normally these two series tend to be highly correlated, resulting in large values of the standard errors, and hence statistical insignificance of either of the variables or both. Technically multicollinearity between them discourages inclusion of both in the equations. Nevertheless they continue to use income in their demand equation regardless of its insignificance.

The difficulties associated with the investigation of electricity demand by the industrial sector on the other hand, as pointed out by Fisher and Kaysen, give the impression that the residential sector may provide an area for deeper investigation. This is the line of thought followed by Wilson[1] who concentrates on this sector trying (i) to analyse the factors that influence its demand for electricity and (ii) to examine the demand for selected major domestic electrical appliances. Towards this purpose he estimates two equations. The first deals with the consumption of electricity per house-

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1 Wilson, J.W., (1971).

hold which is assumed to be determined by (a). the price of electricity (P), (b). the average price of natural gas (G= cents per therm), (c). median family income (Y=dollar per year), (d). average size of housing unit (R=rooms per unit) and (e). climate conditions (c=degree days).
The estimates were derived from a cross-section data sample (reference year 1966) and according to the equation:

$$LogQ = K + b_1 logP + b_2 logG + b_3 logY + b_4 logR + b_5 logC$$

Where the coefficients for P, G, and Y are all statistically different from zero.
The results of particular interest are the substantial negative price elasticity and the negative income elasticity. Since the sample used for estimation is cross-sectional, he interprets his model as representing the long-run demand function, concluding that his results are in sharp conflict with those of Fisher and Kaysen who found little or no influence of price on the long-run demand for electricity. With respect to the adjustment behavior of demand, Wilson, is handicapped by the unavailability of time series data to supplement his cross-sectional analysis. This makes it almost impossible to test the predictive performance of his estimated model as the rate of adjustment cannot be directly estimated.

His second equation attempts to explain variations in the percentage of customers owning a particular appliance. The fitted equations are of the form:

$$S_x = K + b_1 P + b_2 G + b_3 Y + b_4 C \quad \text{and}$$

$$\log S_x = K + b_1 \log P + b_2 \log G + b_3 \log Y + b_4 \log C$$

where S_x is the percentage of homes with at least one unit of appliance x. The sample used consists of 83 SMSAs[1], (reference year 1960), for six electric household appliances, namely, air conditioners, ranges, water heaters, clothe dryers, home food freezers and electric space heating. In general the results corroborate those obtained with electricity consumption as the dependent variable.
The price elasticity is negative and statistically different from zero at the 0.01 level of significance for five of the six appliances (all but air conditioners) and for these five it is less than -1 for all but home freezers; the value for home freezers is -0.94. The values for the others range from -1.77 for dryers to -4.88 for electric space heating. Median income is much less important, both statistically and quantitatively, but the price of natural gas is quite important in the equations for ranges, water heaters, dryers and home freezers.
The exclusive use of cross-sectional data makes it difficult to evaluate the predictive performance of his model. Moreover his income coefficient in the demand equation, obtained in each of the different formulations, is significantly negative. It is strange that this apparent paradox is not investigated by Wilson, nor is it mentioned explicitly in the extensive discussion of his regression

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1 SMSAs = Standard Metropolitan Statistical Areas.

results. The employment of "number of rooms per household" rather than a "number of persons per household" is probably a source of the unexpected negative income elasticity. If, as one would expect, the former variable is an increasing function of income then inclusion of the highly collinear "number of rooms per household" and income variables in the same equation is likely to affect the statistical significance of either of the two variables or both.

The second part of our survey deals with a number of papers, the common characteristic of which is the relatively limited amount of information required for their estimation. In fact the first study by Houthakker and Taylor[1] requires basically information on two appropriate explanatory time series for the econometric estimation of expenditure and price elasticities. The theoretical model developed by Houthakker and Taylor is essentially the reduced form of a system of two equations, in the first of which consumption, q, (for any commodity) is made a function of stocks (s), relative price (p) and total expenditure (x), that is:

$$q = a + bs + \gamma x + \lambda p \qquad (7)$$

and in the second the rate of change in stock ($\dot{s}$) is defined as:

$$\dot{s} = q - \delta s \qquad . (8)$$

1 Houthakker, H.S., and Taylor, L.D., (1970).

The flexible interpretation of the stock variable is an interesting feature of the study. If q relates to the consumption (purchase) of a durable then s is taken to refer to physical inventories. If q represents expenditure on a non-durable then s is defined as psychological stock due to habit formation. This flexiblility is transmitted to the sign of s which is expected to be negative in the case of durables and positive in the case of goods subject to habit formation (the more one has smoked in the past the more one will smoke in the current period). In the specific case of electricity, since s may be taken as the stock of electrical equipment or the accumulated force of habit due to using this equipment in the past, b is expected to be positive; under the latter interpretation because of the reasons provided above, while under the former, because of the technological complementarity between electricity (as an input) and stock of electrical appliances.

Combining equation (7) and (8) one obtains an equation ready for estimation. This, in the case of electricity demand, is as follows:

$$q_t = \underset{(2.81)}{3.71} + \underset{(0.047)}{0.873q_{t-1}} + \underset{(0.0014)}{0.00328x_t} + \underset{(0.025)}{0.0504p_t}$$

$$R^2 = 0.999$$

where: q is personal consumption expenditure for electricity per capita in 1958 dollars, x is total personal consumption expenditure per capita in 1958 dollars,

p is implicit deflator for electricity / implicit deflator for PCE (1958=100).

The short and long-run (mean) elasticities yielded by this equation using annual data during 1947-1964 are as follows:

Elasticities	Income	Price
S.R	0.13	-0.13
L.R	1.93	-1.89

Both elasticities are seen to be low in the short-run but very substantial in the long-run. This is a reflection of b in equation (7) being positive, and can be given either of two equivalent interpretations:(a). If s is taken as referring to the stock of electricity - consuming appliances, it indicates, that the price elasticity of demand is smaller when only utilisation is free to vary (i.e. when the stock is fixed) than when the stock is free to vary. In other words the long-run elasticities give an estimate of percentage change in demand for electricity resulting from a once and for all change in electricity price (or income), and incorporates all the side effects that such an increase in price may have (for example changes in stock held or characteristics of those stocks and so on).(b). If s is taken as the accumulated force of habit from past consumption, it indicates that the services of electricity - consuming appliances are subject to strong habit formation.

Houthakker and Taylor's work can only be treated as an attempt to establish new theoretical foundations applicable to the demand for both durables and non-durables. This is achieved at the expense of a more detailed investigation of the commodities concerned. Prices, for example, other than own price are not considered.

Their work provided the theoretical background for the development of an even more simple version of the above model by Houthakker, Verleger and Sheeham[1], in their analysis of residential electricity demand. They combined time-series and cross-section annual data of state aggregates for the period 1960 - 1971, in order to test what they call a "flow adjustment" hypothesis.

In particular they assume that there is a desired demand q^*_{it} for electricity by individuals in state i at time t. This demand is made a function of income and price:

$$q^*_{it} = f(p_{it}, y_{it}) \tag{9}$$

For simplicity they assume that this function is log-linear:

$$q^*_{it} = a.p^{a}_{it}.y^{\beta}_{it} \tag{10}$$

Further a very simple adjustment process is assumed:

$$\frac{q_{it}}{q_{it-1}} = \left[\frac{q^*_{it}}{q_{it-1}}\right]^{\theta} \tag{11}$$

1 Houthakker, H.S., Verleger Jr., P.K., Sheeham, D.P., (1973).

where $0<\theta<1$. In such a case the estimating equation becomes:

$$Lnq_{it} = \theta \ln a + \theta\gamma \ln p_{it} + \theta\beta \ln y_{it} + (1-\theta)\ln q_{it-1} \quad (12)$$

Both electricity consumption and income are expressed in per capita terms and the price of electricity is represented by the marginal rate per kwh in the 250-500 kwh block as taken from "Typical Electric Bills"[1]. The model is estimated using the error-component technique pioneered by Balestra and Nerlove[2] because it provides a more consistent estimate of the coefficient on the lagged dependent variable. The authors' results are as follows (standard errors are in parentheses):

$$\underset{}{Lnq_{it}} = \underset{(0.029)}{0.104} + \underset{(0.014)}{0.0291\ln p_{it}} + \underset{(0.026)}{0.145\ln y_{it}} + \underset{(0.014)}{0.934\ln q_{it-1}} \quad (13)$$

$R^2 = 0.985$

With the marginal rate per kwh between 100 and 500 kwh's the results are:

$$Lnq_{it} = \underset{(0.029)}{0.072} + \underset{(0.020)}{0.089\ln p_{it}} + \underset{(0.026)}{0.143\ln y_{it}} + \underset{(0.015)}{0.914\ln q_{it-1}} \quad (14)$$

$R^2 = 0.986$

The short and long-run elasticities from these two equations are as follows:

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1 The authors also estimate equations using marginal rates in the 100 - 250 kwh and 100 - 500 kwh blocks.

2 Balestra, P., and Nerlove, M., (1966).

Equation (13)	Income	Price
S.R.	0.15	-0.03
L.R.	2.20	-0.44
Equation (14)		
S.R.	0.14	-0.09
L.R.	1.64	-1.02

The principal difference between the two equations lies in the estimates of the long-run elasticities.

The major critisism against such a model is that it gives rise to an identification problem that will be discussed in some detail in chapter 3.
It will contribute considerably to the understanding of the problem though, if it is shown that one may arrive at the same reduced form equation on the basis of different assumptions about the dynamics of consumers' decision making. More specifically we will discribe briefly, in what follows, a model proposed by Balestra[1] for the gas market which may easily be adopted and applied in the field of electrical energy demand.

After estimating a rather unsatisfactory static "price-income" model, Balestra considers a model which incorporates the complementary modification. This model was developed from the identity:

$$G = S.\ U \tag{15}$$

where S is the total stock of gas appliances per head,

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1 Balestra, P., (1967).

and U is their average utilisation rate, and G the quantity of gas demanded. It was postulated that:

$$U = b_1 + b_2 \log(I/p) + b_3 \log(P/p) + u \qquad (16)$$

and

$$S_t = (1+K)S_{t-1} \qquad (17)$$

Appropriate substitutions lead to a model identical to that used by Fisher and Kaysen in their short-run analysis. In this model the results were very poor in terms of the values of the multiple correlation coefficients and the Durbin-Watson statistics. This, according to the author, was due to the exclusion of dynamic effects which could be allowed for in two ways: either by including lagged values in the expression for U' or by dropping the assumption of a constant rate of growth of S. The latter requires either that S be included explicitly in the estimated equation, or that S be respecified as a function of other variables. In developing his dynamic model, Balestra introduced the concept of the "total demand for fuel"[1]; the model also introduces the complementary modification without using any data on appliance ownership; several simplifications are made instead:

1. The stock of all fuel-using appliances, S_t is assumed to depend only on current real income per head and popu-

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1 "Total demand for fuel" is the demand for all different forms of fuels existing in the economy in any given time period.

lation N:

$$S_t = b_1 + b_2(I/p) + b_3N_t \qquad (18)$$

2. The utilisation of this stock is assumed constant:

$$U_t = U \qquad \text{for all } t \qquad (19)$$

3. All adjustment to a new equilibrium level of S_t takes place within the same year,

4. The depreciation rate is equal to the scrapping rate, (i.e. scrapping is the only way in which appliances are "consumed"), and appliances are not scrapped in the period in which they are acquired.

5. The above four conditions are assumed to apply to the stock of gas appliances as well. They are scrapped at the rate r_g.

The new demand for gas in year t, that is, the demand arising from the use of appliances newly acquired in year t, is then:

$$G^*_t = G_t - (1-r_g).\ G_{t-1} \qquad (20)$$

and the new demand for all fuels

$$F^*_t = F_t - (1-r).\ F_{t-1} \qquad (21)$$

where F_t is the quantity demanded of all fuels in British Thermal Units. Unlike the portion of demand committed to the existing stock of appliances at the beginning of period t (represented by $(1-r_g).\ G_{t-1}$) which is assumed insensitive to relative price changes, the new demand for gas, G^*_t, is assumed to depend only on the relative price of gas, P_{gt}, and the total new demand for all fuels:

$$G^*_t = a_1 + a_2P_{gt} + a_3F^*_t \qquad (22)$$

The model was estimated firstly from cross-section data for 1962 and then from pooled cross-section and time-series data. The principal result is that the demand for natural gas (new demand) is price inelastic.

Replacing G_t^* and F_t^* in (22) by their equals from (20) and (21) one gets:

$$G_t - (1-r_g).\, G_{t-1} = a_1 + a_2 P_{gt} + a_3 \left[F_t - (1-r).\, F_{t-1} \right] \quad (23)$$

or after rearranging:

$$G_t = a_1 + a_2 P_{gt} + a_3 \left[\Delta F_t + r F_{t-1} \right] + (1-r_g).\, G_{t-1} \quad (24)$$

which depends on what assumption one makes about F.

If the latter is assumed to depend on variations in income for instance[1] then the reduced form of (24) becomes:

$$G_t = c_1 + c_2 P_{gt} + c_3 \Delta Y_t + c_4 Y_{t-1} + c_5 G_{t-1} \quad (25)$$

The above equation is very similar in estimating form, to that developed by Houthakker, Verleger and Sheeham[2], given that in general it expresses that demand in period t depends on variations in relative prices and other economic factors as well as demand in the previous period. However recall that while in that formulation the coefficient of lagged demand represented an estimate of the

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1 In fact Balestra assumes that it depends on variations in population as well. This however does not alter the essence of the argument.

2 This may be seen by assuming, for simplicity, that desired demand in period t is a function of ΔY_t, Y_{t-1} and relative prices.

adjustment speed between actual and desired demand in the above formulation $c_5 = (1-r_9)$, where r_9 is the depreciation rate of gas appliances. This, as will be shown later, is conceptually disturbing, particularly if one does not have any a priori (exogenous) information about the average depreciation rate of the underlying stock of consuming equipment.

The general conclusion that may be drawn from the previous discussion is that, given the technological nature between demand for electricity (D_t) and the underlying stock of electricity consuming appliances (S_t), a distinction between demand in the short-run and demand in the long-run is essential. This distinction should not be made with reference to time but with respect to changes in the factors appearing in the relationship:

$$D_t = U_t \cdot S_t$$

where U_t is the average rate of utilisation of S_t.

If the economist had the opportunity to conduct controlled experiments then keeping S_t constant he would be able to observe variations in D_t and interpret them as due to variations in U_t, the latter being the outcome of changes in economic conditions. The economist in most cases (particularly those relating to desk research) hardly has this opportunity, due to financial and temporal constraints. What he observes is the combined outcome of changes in both U_t and S_t which in turn are the outcomes of economic decisions. In trying to analyse demand variations with the help of regression techniques which up to a point[1] may be considered as the equivalent of laboratory controlled experiments, explicit estimates of S_t and, if possible U_t, are needed. Lacking such information in the case of energy products' demand, general approximations, on the basis of more or less heroic assumptions may be made. A convenient assumption for the analysis of short-run demand is that made by Fisher and Kaysen, about a smooth exponential growth of the underlying (and unknown) consuming stock. In subsequent chapters we will adopt this assumption in a very simplistic form and examine its implications. Long-run demand will be seen under the identification problem mentioned previously and discussed in some detail in chapter 3.

1 This relates to the crucial ceteris paribus assumption.

Chapter 3

Formulation of the Relationships

3.1 Introduction

The derivation of demand relationships from time series data requires a combination of ideas, methods and concepts from several different disciplines.
A theoretical formulation of demand relationships is based on the theory of consumer demand. This theory resting on definite assumptions about consumer behaviour, permits hypotheses to be stated about the factors affecting demand, such as income and prices and the interrelationships of these influences. Nevertheless it would be possible to ignore the theory and start with a common-sense or empirical approach. However in doing so we would throw away much useful information about consumers' behaviour that is contained in the postulates of the theory of consumer demand.
Moreover the need to specify the exact form of the relationships arises from two major considerations. First, economic theory involves many simplifications and cannot, therefore, specify the demand relationships exactly. Second, in practice, it is difficult to obtain adequate observations, making it necessary to specify the form of the demand relationships in terms of available data. Therefore, it is necessary to provide a specific mathematical formulation of the interrelationships of variables entering

into the equations[1]. This formulation will depend upon common-sense considerations, ease of computation, and its simplicity in reflecting the parameters of the theory.

3.2 Model Formulation

Electricity does not yield utility in and of itself, but rather is desired as an input into other processes or activities that do yield utility. All these activities utilise a capital stock of some durability (lamps, stoves, water heaters etc.), and electricity provides the energy input. The demand for electricity is thus a derived demand, derived from the demand for the output of the processes in question. Thus, since durable goods are involved, the demand for electricity may be seen as arising from the choice of a utilisation rate of the existing capital stock.

Therefore it may be postulated that:

$$Q_t = U_t . S_t \qquad (1)$$

where:

Q_t is the total quantity in kilowatt-hours, demanded by the community during time period t.

U_t is the intensity of use of the existing capital stock possessed by the community during t, expressed in kilowatt-hours per time period per unit of

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1 See Malinvaud, E., (1970), p.p. 49-59; Cramer, J.S., (1971), pp. 3-9 and Koutsoyiannis, A., (1973), pp. 11-16.

electricity using appliances.

S_t is the total stock of electricity using appliances possessed by the community during t.

$t = 1, \ldots\ldots, T$ is the total number of time periods in the historical interval under consideration, T.

At this stage it would be advisable to express the total stock of appliances in the community S_t as the product of the total number of customers $(NC)_t$ times the average stock of appliances held by the "average" customer $(S')_t$, that is:

$$S_t = (S')_t \cdot (NC)_t \qquad (2)$$

If we substitute (2) into (1) we get:

$$Q_t = U_t \cdot (S')_t \cdot (NC)_t \qquad (3)$$

The variable "number of customers" refers to individuals as well as industrial and commercial establishments. One might argue here that the use of "population" rather than "number of customers" could be another alternative since a simple way to express the total stock of electricity appliances in the community could be to multiply the average stock of appliances possessed by the average individual by the total number of persons in the community. However, this is not altogether satisfactory because in the first place the quantity of electricity consumed by an industrial establishment is much greater than the quantity consumed by an individual, so that if the proportion of industrial establishments in the community is changing, the use of total population as an explanatory variable or the formulation of the dependent variable so as to show consumption per capita, would lead to figures that would be not only misleading but would also be inaccurate in their movement over time. In the second place, and to the extent that individuals may be billed twice both as heads of a household and as owners of a commercial unit , use of a population variable, either as an explanatory factor or as a divisor, would lead to unsatisfactory results. Given the above reasons it seems that the total number of customers $(NC)_t$ constitutes a more satisfactory variable than population for the purposes of this investigation. This point is particularly important in view of the disaggregation of total demand into demand by different sectors which is proposed below.

Equation (3) as it stands refers to electricity demanded by the community as a whole without any reference to different economic sectors. Thus investigation of total demand would imply that different groups of consuming units such as private households, industrial units and commercial customers, react to changes in economic magnitudes in exactly the same way, which is obviously a wrong assumption. For example, since for an industrial unit electricity is mainly a production input, demand for electricity would be a function of the output produced, technology and so on. On the other hand, household demand for electricity may be affected by changes in real disposable income, price of electricity, and an index of the general cost of living and so on. Thus the first step towards a proper investigation of electricity demand should be an attempt to define different groups of consuming units that are more or less homogeneous. Of course, perfect homogeneity cannot be achieved through disaggregation (unless one has at one's disposal highly disaggregated data), since there may exist differences in behaviour among members of the same group. Nevertheless these differences may reasonably be expected to be smaller between different household units than between, for example, the average industrial and residential customer. The available information permits disaggregation of total electricity demand into the following three categories:

1. Demand by households (Q_1) referring to demand for domestic purposes under individual contracts.
2. Commercial demand (Q_2) referring to demand by customers engaged in selling, warehousing or distributing a commodity in some business activity or in a profession (offices, hotels, stores, clubs and so on). The commercial category includes a residual part of electricity demanded by agriculture, interdepartmental and governmental use and railroads; and
3. Industrial demand (Q_3) referring to demand by customers engaged in a process which creates a product.

Therefore the previous equation (3) is now defined at a sectoral level, that is:

$$(Q_i)_t = (U_i)_t \cdot (S_i')_t \cdot (NC_i)_t \tag{4}$$

where i= 1,2,3

1: household sector

2: commercial sector

3: industrial sector

Given that total demand $(Q_T)_t$ is the sum of individual (sectoral) demands we also have:

$$(Q_T)_t = \sum_{i=1}^{3} (Q_i)_t \tag{5}$$

Two problems arise at this stage: The first is the consideration of the utilisation rate. In the short-run consumers may be able to control electricity consumption by varying the intensity of use of their existing equipment. Therefore, in the short-run a demand study is reduced to the examination of the factors influencing the level of use of the given stock of appliances; in other words, it is reduced to the replacement of the unknown rate of utilisation for each sector, $(U_i)_t$, by a set of observable economic variables, variations in which are assumed to satisfactorily approximate variations in that rate. The second problem relates to the stock of consuming appliances for each sector. In the long-run it is probable that customers are able to modify their stocks in such a way as to affect electricity demand significantly. Therefore a long-run demand study is a study of the factors influencing the rate of growth of appliances. Unfortunately actual estimates of this stock do not exist; the problem is then to construct a demand equation explicitly containing a "stock effect" which may be eliminated by appropriate mathematical manipulations. Thus actual estimates of the stock of appliances are not necessary.

3.3 Short-run Analysis

3.3.1 Variations in the Rate of Utilisation

Without considering the peculiarities that might arise when dealing with each particular sector, the rate of utilisation of electricity using appliances may generally be considered, as a first approximation, as a function of certain broadly defined determinants. These, following C. Robinson[1] may be classified as:

1. Activity Indicators (I);
2. Substitution Relationships between electricity and other products or services (R);
3. Weather Conditions (W); and
4. All Other factors that cannot be conveniently quantified, the influence of which is allowed for by the inclusion of a random variable e_{it}.

Thus in general the rate of utilisation may be expressed as:

$$(U_i)_t = f_i \left[(I_i)_t, (R_i)_t, (W_i)_t, e_{it} \right] \qquad (6)$$

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1 . Robinson, C., (1974).

Now, as for the substitution relationships $(R_i)_t$, these are supposed to be taken into account adequately by considering variations in the price of electricity $(P_i)_t$, and variations on the prices of all other remaining products summarised by an appropriate general price index $(PI_i)_t$.

As for the climatic conditions $(W_i)_t$ we take the view that these are particularly important when one deals with quarterly data, since differences in temperature are normally considerable between different quarters. With annual data, variations in the rate of utilisation due to variations in temperature may safely be assumed as negligible. Moreover, a temperature variable due to its nature (purely random variable) may be assumed to be represented by the error term e_{it}.

The activity indicators that were selected as most relevant for each particular sector will be discussed later.

Thus in the case of annual observations the rate of utilisation for each sector may in general be expressed as:

$$(U_i)_t = f_i\left[(I_i)_t,\ (P_i)_t,\ (PI_i)_t,\ e_{it}\right] \qquad (7)$$

Substituting (7) into (4) one gets:

$$(Q_i)_t = f_i\left[(I_i)_t, (P_i)_t, (PI_i)_t, e_{it}\right] \cdot (S_i')_t \cdot (NC_i)_t \qquad (8)$$

If we divide both sides of the above equation by $(NC_i)_t$, the number of customers in each sector, we obtain:

$$\frac{(Q_i)_t}{(NC_i)_t} = f_i\left[(I_i)_t,\ (P_i)_t,\ (PI_i)_t,\ e_{it}\right].\ (S_i')_t \qquad (9)$$

or

$$(q_i)_t = f_i\left[(I_i)_t,\ (P_i)_t,\ (PI_i)_t,\ e_{it}\right].\ (S_i')_t \qquad (10)$$

which is a demand function defined at a per average customer level, for all sectors, Furthermore if the function f_i is expressed in an exponential form, then the average demand per customer of each sector may be expressed as:

$$\left.\begin{aligned}(q_1)_t &= A.\ (I_1)_t^{a_1}.\ (P_1)_t^{a_2}.\ (PI_1)_t^{a_3}.\ (S_1')_t.\ e_{1t}\\ (q_2)_t &= B.\ (I_2)_t^{b_1}.\ (P_2)_t^{b_2}.\ (PI_2)_t^{b_3}.\ (S_2')_t.\ e_{2t}\\ (q_3)_t &= C.\ (I_3)_t^{c_1}.\ (P_2)_t^{c_2}.\ (PI_3)_t^{c_3}.\ (S_3')_t.\ e_{3t}\end{aligned}\right\} (1')$$

The only unknown variable in the above relationships is the stock of equipment held by the average customer in each sector $(S_i')_t$. However, this difficulty, which is due to data unavailability, may be overcome as explained in the following section.

3.3.2 Elimination of the stock variable $(S_i')_t$

Unavailability of stock of equipment data is not a problem in this study only. It characterises most[1] studies of electricity and energy products demand. In order to

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1 See also chapter 2, Introduction, p. 20.

overcome this problem Fisher and Kaysen in their study of electricity demand[1] constructed their own stock series according to information mainly supplied by electricity utility industries. However, as they themselves admit, the quality of this data ranges "from somewhat below the sublime to a bit above the ridiculous"[2].

In their short-run analysis of demand for electricity they get rid of the stock variable by eliminating it from their estimating equations. Balestra in his study "The demand for Natural Gas in the United States"[3] overcomes this difficulty in much the same way. Accordingly it is assumed that in general $(S_i')_t$ follows an exponential smooth trend at a constant rate δ, that is:

$$\text{In period } t \quad : (S_i')_t = (S_i')_o \cdot e^{\delta t} \qquad (11)$$

$$\text{In period } t-1 : (S_i')_t = (S_i')_o \cdot e^{\delta(t-1)} \qquad (12)$$

where $(S_i')_o$ stands for the average stock of electrical equipment held by the average customer at the beginning of the period under investigation. Taking logarithms (base e) of both sides of equations (11) and (12) one obtains:

$$\text{Ln}(S_i)_t = \ln(S_i)_o + \delta t \qquad (13)$$

$$\text{Ln}(S_i)_{t-1} = \ln(S_i)_o + \delta(t-1) \qquad (14)$$

Subtracting (14) from (13) one has:

$$\Delta \ln(S_i')_t = \delta \qquad (15)$$

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1 Fisher and Kaysen, (1962).

2 Fisher and Kaysen, (1962), p.27.

3 Balestra, P., (1967), pp. 19-21.

There is good reason to think that the assumption made above is not very unrealistic particularly as regards the residential and commercial sectors. First, one may reasonably assume that because of a "demonstration effect", the number of appliances sold is proportional to the number already in use and, second, due to an exponential growth in population or an exponential growth in the number of wired establishments, the stock would probably tend to grow exponentially. It seems reasonable to adopt the above procedure and after elimination of the stock variables to obtain estimates of the parameters of system (1′). The great advantage of such a procedure is that while the estimates will depend on the exponential growth assumption, they will be independent of measurements of the stock of appliances. It follows then, that logarithmic transformation of the behavioural equations of system (1′) leads to:

$$(2')\begin{cases} \ln(q_1)_t = \ln A + a_1\ln(I_1)_t + a_2\ln(P_1)_t + a_3\ln(PI_1)_t + \ln(S_1')_t + e_{1t} \\ \ln(q_2)_t = \ln B + b_1\ln(I_2)_t + b_2\ln(P_2)_t + b_3\ln(PI_2)_t + \ln(S_2')_t + e_{2t} \\ \ln(q_3)_t = \ln C + c_1\ln(I_3)_t + c_2\ln(P_3)_t + c_3\ln(PI_3)_t + \ln(S_3')_t + e_{3t} \end{cases}$$

In period (t-1) the following relationships hold:

$$(3')\begin{cases} \ln(q_1)_{t-1} = \ln A + a_1\ln(I_1)_{t-1} + a_2\ln(P_1)_{t-1} + a_3\ln(PI_1)_{t-1} + \ln(S_1')_{t-1} + e_{1t-1} \\ \ln(q_2)_{t-1} = \ln B + b_1\ln(I_2)_{t-1} + b_2\ln(P_2)_{t-1} + b_3\ln(PI_2)_{t-1} + \ln(S_2')_{t-1} + e_{2t-1} \\ \ln(q_3)_{t-1} = \ln C + c_1\ln(I_3)_{t-1} + c_2\ln(P_3)_{t-1} + c_3\ln(PI_3)_{t-1} + \ln(S_3')_{t-1} + e_{3t-1} \end{cases}$$

Subtracting the corresponding elements of (3′) and (2′) the following system is obtained:

$$(4')\begin{cases}\Delta\ln(q_1)_t = a_1\Delta\ln(I_1)_t + a_2\Delta\ln(P_1)_t + a_3\Delta\ln(PI_1)_t + \Delta\ln(S_1)_t + v^1_{1t}\\ \Delta\ln(q_2)_t = b_1\Delta\ln(I_2)_t + b_2\Delta\ln(P_2)_t + b_3\Delta\ln(PI_2)_t + \Delta\ln(S_2)_t + v_{2t}\\ \Delta\ln(q_3)_t = c_1\Delta\ln(I_3)_t + c_2\Delta\ln(P_3)_t + c_3\Delta\ln(PI_3)_t + \Delta\ln(S_3)_t + v_{3t}\end{cases}$$

Substitution of $\ln(S_i')_t$ by its equal from equation (15) leads to:

$$(5')\begin{cases}\Delta\ln(q_1)_t = \delta_1 + a_1\Delta\ln(I_1)_t + a_2\Delta\ln(P_1)_t + a_3\Delta\ln(PI_1)_t + v_{1t}\\ \Delta\ln(q_2)_t = \delta_2 + b_1\Delta\ln(I_2)_t + b_2\Delta\ln(P_2)_t + b_3\Delta\ln(PI_3)_t + v_{2t}\\ \Delta\ln(q_3)_t = \delta_3 + c_1\Delta\ln(I_3)_t + c_2\Delta\ln(P_3)_t + c_3\Delta\ln(PI_3)_t + v_{3t}\end{cases}$$

These are (system 5') the equations to be estimated for each particular sector in the short-run.

3.4 The Long-run Analysis

While electricity is a perishable product its demand due to technological reasons is strictly associated, and to a great extent governed by the existence of electricity using appliances.

Thus short-run variations in quantity demanded are explained in terms of variations in the rate at which the appliances are utilised. In the long-run the rate of utilisation is of secondary importance and therefore

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1 Where the v'_{it} represents composite error terms, equal to the difference of the corresponding error terms in the original equations (2') and (3').

the demand for electricity is essentially the demand for the stock of electricity using appliances. Here one may distinguish two different approaches: the first approach which may be called the direct approach, involves a study of the factors that are likely to influence demand variations in electricity consuming appliances and it has been followed by Fisher and Kaysen. There is, however, a considerable problem associated with the direct approach and this is the question of data availability which in the case of Greece is particularly acute as it was pointed out earlier (page 53). The second approach, which may be called the indirect approach, overcomes the problem of stock data requirements and it is developed in what follows.

The stock of electricity using appliances is explicitly introduced into the demand equation and it is eliminated by appropriate mathematical manipulations based on reasonable assumptions. One of the interesting features of this approach is that it is "logically consistent and has the great advantage of simplicity"[1].

The common characteristic of demand models for products such as electricity, which because of their nature are strictly associated with durables, is the underlying assumption of the existence of the "stock adjustment mechanism". Adoption of such an assumption renders the model dynamic and thùs the models so constructed are known

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1 Balestra, P., (1967), pp. 44-52.

as dynamic models. It should be pointed out that a desire of some economists and econometricians to escape from the boundaries of the traditional demand theory and dynamise it was first attempted through the incorporation of a time trend factor into the demand equation. This is the position initially taken by Stone[1]. However, it is generally accepted now that such a treatment is not very satisfactory. Thus dynamisation of models has been attempted through formulation based on assumptions of lagged reactions and so on. The approach adopted in this work has its roots in a study by Houthakker and Taylor, who assume that the demand for a product, apart from relative prices and income, is a function of the existing level of the relevant stock. In the case of non-durables this is a rather psychological concept due to the "habit formation". The elimination of stock from the demand equation takes place after suitable manipulations, so demand is explained uniquely by reference to price and income together with lagged values of the dependent variables.

The choice of a form for the demand equation to be estimated must take into consideration the distinction between customers who, because of the costs involved when altering their stock of appliances and equipment choice, stay locked into particular patterns of energy

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1 Stone, R., (1954).

use and those willing to make major changes in their stock. Customers in the locked-in category are likely to be sensitive to changes in their economic environment. A relatively low variable - to - fixed cost ratio for most types of electricity using devices makes the locked-in demand for electricity nearly, if not totally, unresponsive to changes in income and electricity prices. By contrast, electricity demand may be significantly affected by the final choice of those customers who are at the decision making stage regarding the kind of equipment to be purchased (oil consuming, electricity consuming and so on). For this category fixed as well as running costs of different equipment satisfying the same need may be of importance. From this point of view increases in electricity demand may be seen as reflecting additions to the already existing stock of electricity consuming equipment the latter reflecting the influence of variations in relative prices and income.

The basic idea which underlies the long-run demand model is the consideration of demand that has its roots in the flexible market of electricity, that is the incremental or flexible electricity demand (inclusive of replacement). This idea which has been put forward by Balestra leads to the formulation of a dynamic demand model the main stages of which are the following:

Let us consider the quantities $(Q_i)_t$ and $(Q_i)_{t-1}$ which represent the total quantities of electricity demanded by each sector in period t and (t-1) respectively.

The increment in total electricity demanded by each sector is given by:

$$\Delta(Q_i)_t = (Q_i)_t - (Q_i)_{t-1} \qquad (16)$$

The quantitiy $\Delta(Q_i)_t$ represents the change in total electricity demanded by sector i between period t and (t-1) but it does not express the total "flexible" demand for electricity by that sector.

If, for example, the total stock of electricity consuming appliances possessed by sector i during period (t-1) is represented by $(S_i)_{t-1}$ and if $(U_i)_{t-1}$ denotes the average rate of appliance utilisation during (t-1) then:

$$(Q_i)_{t-1} = (U_i)_{t-1} \cdot (S_i)_{t-1} \qquad (17)$$

Similarly in period t we will have:

$$(Q_i)_t = (U_i)_t \cdot (S_i)_t \qquad (18)$$

Assuming that the utilisation rate (U_i) remains more or less constant over time that is:

$$(U_i)_1 = (U_i)_2 = (U_i)_3 = \ldots\ldots = (U_i)_t = (U_i)$$

we have:

$$(Q_i)_{t-1} = (U_i) \cdot (S_i)_{t-1} \qquad (19)$$

and $$(Q_i)_t = (U_i) \cdot (S_i)_t \qquad (20)$$

From the above two equations it may be easily seen that incremental denand $\Delta(Q_i)_t$ could be considered to coincide with flexible demand $\left[\text{call it } (Q_i)^*_t\right]$ only if there was no scrapping of the underlying consuming appliances at any period. This however is totally unrealistic. Appliances do deteriorate and some of them are scrapped during each period. If we denote this unknown scrapping rate by λ_i, then if $(S_i)_{t-1}$ is the total stock in period (t-1), only

$$(1-\lambda_i).(S_i)_{t-1} \qquad (21)$$

will continue to be used one period (year) later. If, on the other hand, we denote by $(K_i)_t$ the new appliances purchased (replacement plus net additions to the remaining stock) during period t, the stock of appliances during t will be equal to:

$$(S_i)_t = (1-\lambda_i).(S_i)_{t-1} + (K_i)_t \qquad (22)$$

Multiplying both sides of (22) by the (assumed constant) average rate of utilisation of appliances we obtain:

$$(U_i).(S_i)_t = (1-\lambda_i).(S_i)_{t-1}.(U_i)+(U_i).(K_i)_t \qquad (23)$$

which may be written as:

$$(Q_i)_t = (1-\lambda_i).(Q_i)_{t-1} + (U_j).(K_i)_t \qquad (24)$$

The term $(U_i).(K_i)_t$ as representing demand arising from newly purchased appliances, is what was previously called flexible demand. Denoting this be $(Q_i)^*_t$ the above equation (24), takes the form:

$$(Q_i)_t = (Q_i)^*_t + (1-\lambda_i).(Q_i)_{t-1} \qquad (25)$$

which simply states that demand in period t is the sum of flexible demand and the demand arising from the remaining period (t-1) appliances. Note that $(Q_i)^*_t$ is different from $\Delta(Q_i)_t$. This may be seen by expressing (25) as:

$$(Q_i)_t = (Q_i)^*_t + (Q_i)_{t-1} - \lambda_i.(Q_i)_{t-1} \qquad (26)$$

or

$$(Q_i)^*_t = (Q_i)_t - (Q_i)_{t-1} + \lambda_i . (Q_i)_{t-1} \qquad (27)$$

or

$$(Q_i)^*_t = \Delta(Q_i)_t + \lambda_i . (Q_i)_{t-1} \qquad (28)$$

$(Q_i)^*_t$ may be assumed to be a function of an appropriate activity indicator, substitution relationships and so on. Hence if

$$(Q_i)^*_t = f_i\left[(I_i)_t, (R_i)_t\right] \qquad (29)$$

then equation (25) becomes:

$$(Q_i)_t = f_i\left[(I_i)_t, (R_i)_t\right] + (1-\lambda_i). (Q_i)_{t-1} \qquad (30)$$

This equation (after specification of the form of the function f_i and the variables to be included in it) is ready for statistical estimation.

In essence the above relationship indicates that variations in electricity demand are possible only to the extent to which the structure of relative prices and income affects the demand for new electricity consuming appliances (inclusive of replacement). Existing demand is not sensitive to price or income changes (recall that the utilisation rate has been assumed constant. Without such an assumption given unavailability of data relating to the existing stock of appliances no further progress could be made).

The above estimating equation however, is consistent with a totally different interpretation, namely that <u>total demand</u> in period t <u>is</u> sensitive to changes in the economic environment. This may be shown if it is assumed that demand may be analysed on the basis of a "flow adjustment model". Accordingly it is hypothesised that desired demand in period t, $(Q_i)_t^d$, is a function of $(I_i)_t$ and $(R_i)_t$ that is:

$$(Q_i)_t^d = f_i\left[(I_i)_t, (R_i)_t\right] \tag{31}$$

It is also assumed that the adjustment of actual demand $(Q_i)_t$ to desired demand $(Q_i)_t^d$ is not immediate but spread over time according to the following relationship:

$$(Q_i)_t - (Q_i)_{t-1} = p_i\left[(Q_i)_t^d - (Q_i)_{t-1}\right] \tag{32}$$

where p_i denotes the adjustment coefficient for each sector. Substituting (31) into (32) we get:

$$(Q_i)_t - (Q_i)_{t-1} = p_i\left[f_i\left[(I_i)_t, (R_i)_t\right] - (Q_i)_{t-1}\right] \tag{33}$$

or

$$(Q_i)_t - (Q_i)_{t-1} = p_i\ f_i\left[(I_i)_t, (R_i)_t\right] - p_i \cdot (Q_i)_{t-1} \tag{34}$$

or

$$(Q_i)_t = p_i \cdot f_i\left[(I_i)_t, (R_i)_t\right] + (1-p_i) \cdot (Q_i)_{t-1} \tag{35}$$

A comparison of equations (30) and (35) reveals that the same estimating equation supports two quite different models which cannot without other information be identified.

The flexible demand model assumes that existing demand is not influenced by variations in economic factors. In such a model only new demand and replacement demand are likely to be sensitive to economic variables. The flow adjustment type of model assumes that all demand is sensitive to changes in economic variables.

This ambiguity is clearly undesirable and an a priori answer cannot be given. The only thing that may be said is that in the flexible demand model the coefficient of the lagged dependent variable constitutes an estimate of the depreciation rate of the appliances stock, while in the flow adjustment model it constitutes an estimate of the speed with which actual demand adjusts to desired demand. The magnitude of this coefficient is likely to give an indication as to what it represents given the assumptions underlying the two models.

Up to this point the models to be estimated have been discussed in a very general way. Thus the influencing factors have been broadly specified as activity indicators, substitution relationships and so on. A detailed analysis of the precise variables to be included in the electricity demand equations, as well as the estimation of the models developed here, are taken up in the following chapter.

Chapter 4

Estimation of the Relationships. Evaluation of the Results and Conclusions.

4.1 Introduction - The Identification Problem

Having developed the models to be estimated in very general terms, the next stage is the derivation of numerical estimates of the coefficients of these models. However, up to now the analysis has been carried out on the implicit assumption that what we are trying to construct are the demand curves relating to the household, commercial and industrial sectors. The data that we are going to use for the statistical estimation though, refer to quantities sold and corresponding prices, or in other words, they consist of points of equilibrium between the demand and supply relationships. Our data refer to different time periods and consequently they must be considered as the outcome of shifting demand and supply schedules. But then, as H. Schultz[1] has put it: "Is it possible to deduce statistically the theoretical demand (or supply) curve when we know only the coordinates of the points of intersection of the theoretical (unknown) demand curve with the theoretical (unknown) supply curve

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1 Schultz, H., (1938), p.p. 72-73.

at different points of time?". An answer to this question is given by Haavelmo[1]. He suggests that estimation should be carried out on the basis of a complete system of equations including both a demand and a supply function. R. Stone[2], analysing the problem of indentification at a theoretical level, points out that even for the purpose of studying single relationships, the need of constructing complete and identified systems is important. Moreover, despite that he estimates his demand function by single equation methods.

The electricity market can be argued to be one of the situations where use of single equation estimation methods is permitted. Two main reasons may be advanced in support of this argument:

1. <u>Institutional Characteristics</u>[3]

Equilibrium in a competitive market is reached after confronting all demands with all supplies. Sales of a product are all concluded at the same price which must be exactly the price which leaves neither unsatisfied demand nor surplus supply. In such a simple model there are only endogenous variables. Thus specification of the demand and supply functions is sufficient

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1 Haavelmo, T., (1943).

2 Stone, R., (1954), pp. 244-249.

3 See also Cramer, J.S., (1969), p. 213.

to determine completely the equilibrium values of the quantities demanded, supplied as well as the equilibrium price.

The situation in the electricity market is different. The price at which consumers buy the quantities desired is not the outcome of the simultaneous interaction of supply and demand. It rather reflects decisions taken by the authorities (the Government and a Board of Directors), based on the view that electricity is a public utility. Thus exogenous regulation of electricity price permits the conclusion that it would be realistic to consider it as an exogenous variable determined outside of a demand and supply system. Hence, considering the price variable "as given" in the demand equation our estimates are unlikely to be distorted seriously.

2. Supply Conditions[1]

For short periods of time the supply of electricity to residential and commercial customers may approximately be considered as perfectly elastic. This is due to the fact that the major industrial customers after an agreement with the PPC are supplied with electricity through different networks. In this way supply to the residential and commercial customers is not interrupted. On the other hand stations generating electricity are constructed with the purpose in mind of satisfying not only

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1. See also chapter 1, pp. 5 - 12.

immediate but also future consumption. Excess capacity is generated in the expansion process of a heavily capitalized industry such as the electricity industry. The following table shows the different levels of capacity and production of electricity in Greece for the years 1969 - 1974.

TABLE 4.1

Year	Capacity in GWH	Production in GWH	Utilisation of capacity %
1969	20,051.6	8,158	40.7
1970	21,856.2	9,198	42.7
1971	23,520.6	10,979	46.7
1972	25,027.3	12,201	48.8
1973	30,160.7	13,742	45.6
1974	33,244.2	13,908	41.8

Sources: "Annual Report and Balance Sheet" for the years 1971, table 4, p. 101 and 1975, table 3, p. 99. PPC Publications, Department of Organisation, Division of Statistics.

The above considerations lead to the conclusion that the supply of electricity to residential and commercial customers may safely be regarded as perfectly elastic for short time periods, thus justifying the use of a single equation method for the derivation of price and income elasticities. The situation is similar for the industrial sector given that the major industrial consumers of electricity are supplied on the basis of prices that are agreed between them and the electricity authorities in advance.

4.2 Short-run Demand for Electricity: Regression estimates

The results for the individual sectors are presented below in tables 4.2 to 4.9. The ordinary least squares method (OLS) was used for the derivation of these results on the basis of 15 annual observations for each sector covering the period 1961 - 1975. Nevertheless, in accordance with the models formulated, before any attempt towards the presentation of these results is made, the variables to be included in the demand equations are discussed in some detail. In the short-run, the analysis[1] concentrates on those factors that are likely to influence variations in the rate of utilisation of the existing capital stock.

For the residential sector the price of electricity, the prices of all other products or services in the form of a consumer price index and disposable income (or consumer expenditure) were selected as explanatory factors.

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1 See chapter 3, pages 51-56.

The justification of using consumers expenditure as an alternative to the more conventional disposable income may be based on the permanent income hypothesis of Friedman. According to this hypothesis expenditures are determined by permanent rather than transitory income. Thus given that the income level recorded in a particular time period may well be distorted by transitory components, total expenditure is likely to be a better explanatory variable in demand studies, since it may reflect changes in permanent income rather than disposable income. Nevertheless the previous argument may easily be reversed if one accepts that total expenditure figures are also likely to be distorted by transitory components since they depend considerably on the actual timing of the purchase of expensive durable goods. If for example a family bought an expensive durable commodity during a certain period then its total expenditure as a proxy variable for permanent income will certainly overstate the level of the latter. From this point of view actual disposable income figures may seen a better indicator of permanent income. Which of the two variables constitutes a better approximation is a rather empirical question. The only thing that may be said is that use of expenditure figures is likely to introduce more variation in the relevant series and thus reduce the tendency of the variables included to move together over time.

The price of electricity is considered to be the second major determinant of the variations in electricity

demand in the short-run. The question arising here is which price variable is the most suitable for the analysis since the consumer of electricity does not face a single price, but rather a price schedule, since electricity is purchased in blocks at a decreasing marginal price. As Houthakker[1] has pointed out, the presence of a price schedule has important implications for the equilibrium of the consumer and therefore for the demand function itself. Use of the marginal price only in the demand equation conveys part of the information required, because a single marginal price governs the behaviour of the consumer while he is in a certain block, but it does not determine why he consumes in that block as opposed to some other block.
If on the other hand only an ex post average price is used, this may lead to problems of simultaneity and identification since the existence of a price schedule with decreasing block tariffs means that the consumer faces a downward sloping supply schedule, defined with respect to the expost average price. Equilibrium then occurs at the price and quantity where demand and supply are equal. The above considerations imply that the best procedure would be to include both a marginal and an average price as explanatory variables in the demand

1 See Houthakker, (1951).

equation. In this case the marginal price would refer to the last block consumed, while the average price would refer to the average price per kwh of the electricity consumed up to, but not including the final block. In this study marginal prices are not used. This is due mainly to the unavailability of information relating to the price prevailing at different blocks. Moreover, given that price is an exogenous factor in the decision making process, (since it is not the outcome of interaction between demand and supply forces in the electricity market, but is regulated by a Board of Directors and of Government authorities) the use of only an average price variable in the demand equation is permissible. In other words, it is assumed that customers observe and react to changes of only one price; that is the average price of electricity.

The third variable which has been used as an explanatory factor in the short-run residential demand function was an overall consumers price index representing the movements of price of all other commodities. It should be noted that this general price index is partly affected by variations in electricity price itself. Nevertheless the error introduced because of this is very small. In contrast with the vast majority of empirical investigations of demand where it is customary to carry out the analysis in terms of real income and real prices, in this study the relevant equations have been estimated with the variables defined in current terms as well. Deflation of economic variables by an overall price index would imply that inflationary or deflationary pressures have no influence on the behaviour of the consumer. In other words the consumer does not suffer from "money illusion". However this is an assumption and as such it has to be investigated and should not be imposed on the relationships formulated. Deaton and Brown in a critical survey on applied demand analysis suggest that:

> "This absence of money illusion is an attractive property for a demand function to possess; nevertheless it may not be true. Consumers may suffer from money illusion and it could be argued that it is part of the task of demand analysis to discover whether or not it exists rather than to use as a starting point a model which precludes it"[1].

The factors that were identified as more relevant explanatory variables in the commercial and industrial demand functions were:

i. Gross Domestic Product and an Index of Industrial Production as the appropriate activity indicators respectively.

ii. The average price of electricity charged to commercial and industrial customers; and

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1 Brown, A., and Deaton, A., (1973), p. 184.

iii. The Wholesale Price Index was used either as a separate variable or as a deflator to convert the values of activity indicators into constant terms.

Before we proceed with the presentation of the results, some general remarks relating to the short-run formulations are necessary. First, it must be noted that despite the likely importance of the prices of substitutes and complements of electricity, it would be wrong to include them in the formulated short-run demand functions. The argument may be established as follows: Consider for example electricity demand in the household sector. At any period this may be defined as:

$$Q_{1t} = U_{1t} \cdot S'_{1t} \cdot NC_{1t}$$

where, as previously, Q_{1t} represents total electricity consumed, NC_{1t} the number of residential customers, S'_{1t} the number of appliances held by the average residential customer and U_{1t} the average rate of utilisation of these appliances during period t. After dividing both sides by NC_{1t} the above equation becomes:

$$\frac{Q_{1t}}{NC_{1t}} = U_{1t} \cdot S'_{1t}$$

Now had we had all the desirable information at our disposal it would be appropriate to express the unknown U_{1t} and S'_{1t} as functions of the corresponding prices of appliances, income, credit availability, the price of electricity and so on.

If on the other hand we had information relating to the number of appliances held by the average customer for all the periods under investigation it would be false to include both the relevant stock figures <u>and</u> the prices of appliances or the prices of competing products. This is simply because inclusion of a stock variable would represent the net effect of the influence of these factors over the years. Hence the fact that we formulated the short-run demand functions in such a way as to eliminate the influence of the stock (the autonomous rate of growth of which is now represented by the constant term of the short-run demand functions) is equivalent to eliminating the influence on stock of the prices of electricity using appliances and so on. It should be noted however, that although such a transformation is mathematically convenient, a great deal depends on the validity of the assumption made regarding the growth rate of the appliances. If the smooth exponential growth assumption is invalid the results reported will accordingly be affected. Nevertheless, given the unavailability of relevant stock data one has to rely upon the most appropriate and convenient assumptions.

The dependent variables as well as the activity indicators appearing as explanatory factors on the left-hand side of each equation are expressed on a per customer basis, with the exception of the index of industrial production, in accordance with the theoretical models developed in chapter 3. First differencing reduced the number of observations to 14.

The estimates of price and "income" elasticities for the individual sectors are presented below in tables 4.2 to 4.9.

4.2.1 Short-run Residential Electricity Demand: 1961-1975

Table 4.2

Equation 1: $\Delta \ln q_1 = \delta_1 + a_1 \Delta \ln(MIPC) + a_2 \Delta \ln(RMP) + u_1$

Explanatory Variables	Parameter	Estimates- Elasticities
1. Constant term	δ_1	0.0336 (5.918)[1]
2. Current Disposable Income per customer (MIPC)	a_1	0.539 (6.594)
3. Money Price of Electricity (RMP)	a_2	- 0.585 (7.549)

R^2 : .860

D-W statistic :2.178

r^2 between independent variables

$r^2_{(MIPC),(RMP)}$: .263

1 The numbers in brackets represent the estimated t-values.

Table 4.3

Equation 2: $\Delta \ln q_1 = \delta_1 + a_1 \Delta \ln(RI/C) + a_2 \Delta \ln(RRP) + u_1$

Explanatory Variables	Parameter	Estimates- Elasticities
1. Constant term	δ_1	0.034 (4.225)[1]
2. Real Disposable Income per customer (RI/C)	a_1	0.602 (4.564)
3. Real price of Electricity (RRP)	a_2	- 0.516 (3.179)

R^2 : .856

D-W statistic : 2.207

r^2 between independent variables

$r^2_{(RI/C),(RRP)}$: .289

1 The numbers in brackets represent the estimated t-values.

Table 4.4

$$\text{Equation 3: } \Delta \ln q_1 = \delta_1 + a_1 \Delta \ln(CE/C) + a_2 \Delta \ln(RMP) + u_1$$

Explanatory Variables	Parameter	Estimates- Elasticities
1. Constant term	δ_1	0.037 (5.569)[1]
2. Current Consumer Expenditure per customer (CE/C)	a_1	0.580 (5.189)
3. Money Price of Electricity (RMP)	a_2	- 0.799 (6.573)

R^2 : .796

D-W statistic : 2.491

r^2 between independent variables

$r^2_{(CE/C),(RMP)}$: .569

1 The numbers in brackets represent the estimated t-values

Table 4.5

Equation 4: $\Delta \ln q_1 = \delta_1 + a_1 \Delta \ln(RE/C) + a_2 \Delta \ln(RRP) + u_1$

Explanatory Variables	Parameter	Estimates- Elasticities
1. Constant term	δ_1	0.022 (2.078)[1]
2. Real Consumer Expenditure per customer (RE/C)	a_1	0.463 (2.013)
3. Real Price of Electricity (RRP)	a_2	- 0.811 (3.943)

R^2 : .696

D-W statistic : 2.299

r^2 between independent variables

$r^2_{(RE/C),(RRP)}$: .063

1 The numbers in brackets represent the estimated t-values.

4.2.2 Short-run Commercial Electricity Demand: 1961-1975

Table 4.6

Equation 5: $\Delta \ln q_2 = \delta_2 + b_1 \Delta \ln(GP/C) + b_2 \Delta \ln(CMP) + u_2$

Explanatory Variables	Parameter	Estimates- Elasticities
1. Constant term	δ_2	0.021 (2.032)[1]
2. Current Gross Domestic Product per customer (GP/C)	b_1	0.769 (2.738)
3. Money Price of Electricity (£MP)	b_2	- 0.752 (3.506)

R^2 : .543

D-W statistic : 2.143

r^2 between independent variables

$r^2_{(GP/C),(CMP)}$: .288

1 The numbers in brackets represent the estimated t-values.

Table 4.7

Equation 6: $\Delta \ln q_2 = \delta_2 + b_1 \Delta \ln(RG/C) + b_2 \Delta \ln(RCP) + u_2$		
Explanatory Variables	Parameter	Estimates-Elasticities
1. Constant term	δ_2	0.011 (2.615)[1]
2. Real Gross Domestic Product per customer (RG/C)	b_1	0.519 (1.808)
3. Real Price of Electricity (RCP)	b_2	- 0.977 (3.525)
R^2		: .591
D-W statistic		: 2.152
r^2 between independent variables		
$r^2_{(RG/C),(RCP)}$		: .0003

1 The numbers in brackets represent the estimated t-values.

4.2.3 Short-run Industrial Electricity Demand: 1961-1975

Table 4.8

Equation 7: $\Delta \ln q_3 = \delta_3 + c_1 \Delta \ln(IIP) + c_2 \Delta \ln(RIP) + u_3$

Explanatory Variables	Parameter	Estimates-Elasticities
1. Constant term	δ_3	0.117 (2.410)[1]
2. Index of Industrial Production (IIP)	c_1	0.974 (2.878)
3. Real Price of Electricity (RIP)	c_2	- 1.151 (1.096)

R^2 : .434

D-W statistic : 1.709

r^2 between independent variables

$r^2_{(IIP),(RIP)}$: .510

1 The numbers in brackets represent the estimated t-values.

Table 4.9

Equation 8: $\Delta \ln q_3 = \delta_3 + c_1 \Delta \ln(IIP) + c_2 \Delta \ln(RP3) + u_3$		
Explanatory Variables	Parameter	Estimates-Elasticities
1. Constant term	δ_3	0.181 (2.882)[1]
2. Index of Industrial Production (IIP)	c_1	1.855 (2.858)
3. Real Relative Price of Electricity (RP3)	c_2	- 0.979 (1.908)
R^2 : .528		
D-W statistic : 1.994		
r^2 between Independent variables $r^2_{(IIP),(RP3)}$: .002		

1 The numbers in brackets represent the estimated t-values.

4.3 Criteria for the evaluation of the Estimates

The evaluation of the estimates derived was made on the basis of certain generally accepted criteria which are briefly outlined below:

a. Economic Criteria: These relate to the sign and the size of the estimates of the demand parameters. The theory of consumer demand dictates that on a priori grounds one should expect a negative relationship between variations in the price of a commodity and its quantity demanded and a positive relationship between the latter and variations in income. In selecting the set of estimated equations to be presented the procedure of dropping a variable if its sign contradicted the a priori expectations was adopted.

b. Statistical Criteria: Given the theory it may be deduced that a certain set of events will occur in a particular way. This constitutes a hypothesis which may be tested by comparison with observed facts. Statistical methodology is concerned with an appropriate test of the statistical hypothesis. This test is based on a comparison of the observed facts with those expected on the basis of repeated random sampling from a specified population. The problems arising from this comparison fall onto two classes First, those concerning the tests of whether or not the observations provide any evidence of the relationship assumed. This is done by dividing a measure of dispersion of the dependent variable into two parts: "explained" and "unexplained" variation. Explained variation is associated with the influence of the determining variables, while unexplained variation cannot be so associated. If the ratio of explained variation to unexplained variation, (in other words if the value of the correlation coefficient) is high, then the null hypothesis, that there is no evidence of relationship, is defeated and the observations are considered to provide evidence of the relationship assumed.

The second problem appears when a test is made of whether there is evidence of any significant influence of one of the determining variables in the relationship. This may be done by comparing the regression coefficient, showing the influence of the variable in question on the dependent variable, with its standard error of estimate.

c. <u>Econometric Criteria:</u> These relate mainly to the following two problems:

i. <u>Autocorrelation:</u> The problem which autocorrelation introduces concerns the variance of the estimators. Specifically, if there is autocorrelation the formulae used for the derivation of the variances of the estimators do not hold. Using these formulae, false t-ratios are generated which render invalidity to the tests of hypotheses about the values of the parameter estimates of the model used. As a result, one might accept as statistically significant an estimated value for a parameter which in fact is not significantly different from zero. Checks for autocorrelation were performed on the basis of the Durbin-Watson d-statistic. Low values of the d-statistic indicate the existence of positive autocorrelation, while large ones suggest that negative autocorrelation exists. In our case the critical values of the d-statistic (5% level) for two explanatory factors were: $d_L = 0.95$ and $d_U = 1.54$[1].

ii. Multicollinearity: This problem arises when the explanatory variables tend to be highly correlated, something which has serious implications for the reliability of the estimates of demand parameters. Given however that it is mainly the degree of multicollinearity which may or may not prove to be disturbing in the particular case at hand, and that there is no generally accepted test for multicollinearity, in evaluating the reliability of our estimates we have adopted a simple rule proposed by Klein[2] who believes that multicollinearity becomes a problem only if it is high relative to the overall degree of multiple correlation,

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1 The tables start from the theoretical values of d_L and d_U when the number of available observations is equal to 15. These values were assumed to be applicable in our case where the number of observations, after taking first differences, reduced to 14.

2 Klein, L.R., (1962), pp. 64 and 101.

that is if:

$$r^2_{x_i x_j} \geqslant R^2$$

where $r^2_{x_i x_j}$ is the simple correlation between any two independent variables and R^2 is the multiple correlation coefficient.

4.4 Short-run Demand for Electricity: Evaluation of the Estimates.

Consideration of the estimates of the short-run electricity demand by the residential sector shows that all coefficients exhibit the correct sign on a priori grounds. They show an inverse relationship between variations in the price of electricity, whether expressed in current prices or in constant (1970) prices. They also suggest that residential demand on the average appears to be price inelastic. This is in accordance with a priori expectations if one considers that in a developing country like Greece electricity satisfies more or less basic needs such as heating, lighting, cooking and so on. The latter consideration seems to be supported by the elasticities of the activity indicators (disposable income and expenditure per customer) tried as explanatory variables in the residential sector, which are well below unity. All price and income elasticities are statistically significant at a 5% level of significance whether a one - tail or a two - tail test is used[1]; (the critical values for the t-statistic for 11 degrees of freedom are 1.8 and 2.2 for the one - tail and two - tail tests respectively).

Another interesting point is that the elasticities derived show a remarkable similarity whether the variables are expressed in current terms or in constant terms. This may be taken to imply that the influence of all other prices, as summarised in the form of a general price index, may be rather weak. Indeed, when this variable was introduced as a separate explanatory factor in the demand equation of tables 4.2 and 4.4, the value of R^2 remained the same (0.86) and the coefficient of the "general price level" (CPI) variable was statistically insignificant (See Appendix 2, table 1). Nevertheless,

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1. In most econometric applications the one - tail test is applicable when one examines the statistical significance of the coefficient of a variable whose qualitative influence is known a priori. Desai, for example testing the significance of an income coefficient points out: ".....If we had used this information (that the true value of the income coefficient should be not only zero but positive) we would see that our test should be a one - tail test, which as a rule is the case in econometrics". See Desai, M., (1976), pp. 61-62.

given that the equations whose explanatory factors were expressed in "real" terms (tables 4.3 and 4.5) are theoretically more acceptable, they may be considered as superior to the ones expressed in current terms.

Consideration now of the reliability of the estimates of the selected equations in tables 4.3 and 4.5, from the point of view of econometric problems, suggests that autocorrelation and multicollinearity are not significant. While the Durbin-Watson statistic is in the neighbourhood of 2, the correlation coefficient between the explanatory factors are remarkably low (0.289 between real price of electricity and real disposable income per customer and 0.063 between real price and real expenditure per customer). The very low value of the latter implies that the expenditure series exhibits much more variation than the disposable income per customer series. However, comparing the explanatory power of these two equations as indicated by the value of the coefficient of determination it may be said that equation 2 (table 4.3) appears to be slightly superior. On the assumption that the coefficients of the latter constitute accurate estimates of the population parameters, the conclusion would emerge that on the average an increase in the real price of electricity by 1% would cause a decrease in the quantity of electricity per customer by almost a half percent. The quantitative impact of variations in disposable income per customer appears to be slightly stronger (around 0.6%).

The constant term constitutes an estimate of the autonomous average rate of growth of the (unknown) stock of electricity using appliances and indicates that the latter grew by 3.5% per year over the period under consideration. Although we have no means to test this indication intuitively it would not seem totally unrealistic.

The elasticities of the short-run commercial demand tabulated in tables 4.6 and 4.7 as in the case of residential demand are satisfactory both from the point of view of signs expected and of their statistical significance. Again the wholesale price index performs better if used as a deflator rather than as a separate variable in the equation expressed in current terms (see Appendix 2, table 2). As table 4.7 shows, commercial electricity demand appears to be fairly insensitive to changes in real Gross Domestic Product per customer since it implies that a 1% change in GDP is associated on average with an almost half percent increase in electricity demanded. The influence of electricity price however is markedly more important than in the residential sector. Its magnitude is almost equal to unity implying equiproportionate changes between price and quantity.

Turning now to the industrial sector, it may be seen from table 4.8 that the results show an almost equiproportionate response of demand to changes in the relevant activity indicator (Index of Industrial Production). Electricity price on the other hand does not seem to affect demand significantly since the estimate of its coefficient is statistically insignificant at the 5% level. An intuitive explanation for this could be given upon consideration of the role which electricity plays in the industrial sector. Here, as pointed out previously, electricity constitutes a production input. But production processes are associated in the majority of cases with a particular combination of inputs that, at least in the short-run, cannot be changed. Thus since substitution of other fuels for electricity according to our model was ruled out in the short-run, the influence of a price change would mainly be reflected by a change in industrial capacity utilisation, and this in turn by a change in electricity demand. However, a decrease in capacity utilisation after a price increase of electricity would be a reasonable assumption only if electricity were a major input in the production process. But this is clearly unrealistic. Other costs such as labour costs, rent and so on are important and hence an increase in the price of electricity alone, although it would result in an increase in the average price of the final output produced, would be unlikely to cause a significant change in capacity utilisation. Moreover to the extent to which the industrial customer is in a position to pass on to final consumers an increase in input costs, one would expect that industrial electricity demand is likely to be non-sensitive to electricity price changes, at least within the range of experienced prices.

Looking at the performance of the demand equation from a purely technical point of view, it may be seen that although there is no indication of the presence of autocorrelation, multicollinearity appears to be rather harmful, as may be seen by a comparison of the values of r^2 (= 0.510) with the overall goodness of fit of the equation R^2 (= 0.434). Nevertheless, such a test is rather a technical one and may not be offered as a proper economic explanation. It might well be that with respect to the industrial sector the assumption that the price of competing fuels (mainly oil) does not affect short-run variations of electricity demand is far from realistic. Using relative price of electricity (deflated by the price of oil instead of an index of wholesale prices) resulted in a significant improvement in our results.

Under this new formulation as table 4.9 suggests demand appears to be highly elastic with respect to variations in the Index of Industrial Production and as having just about unitary elasticity with respect to the relative price of electricity. Moreover the value of the D-W statistic (d= 1.994) and the value of r^2 (=0.002) as compared with that of the coefficient of determination (R^2 = 0.528) suggests that the problems of autocorrelation and multicollinearity might not be serious in this case. Although an undesirable degree of volatility characterises the two sets of estimates of tables 4.8 and 4.9, considering the nature and the changes that took place in the industrial sector during the period under investigation it may be said that the estimates of table 4.9 are not altogether unrealistic. Particularly during the first part of the period under consideration, vital for the economy's industrialisation, investment projects were undertaken with particular emphasis in fields where considerable amounts of electricity were required. A comparison of changes in the index of industrial production and an Index of electricity consumption by the industrial sector, indicates that increases in the output produced were accompanied by more than proportionate increases in electricity consumed (table 4.10). The fast rate of industrialisation on the other hand and the larger and larger amounts of electricity required to achieve the economy's modernisation on the other, make the demand for electricity sensitive to changes in the output produced even in a short time period.

4.5 Short-run Demand for Electricity: Conclusions

The short-run analysis was in effect the analysis of factors influencing the utilisation rate of the existing appliances stock. In order to isolate variations of this rate it was assumed that the appliances stock follows a smooth exponential trend over time which enabled elimination of the stock variable from the short-run demand equations. Therefore the results obtained should

Table 4.10

Year	Index of Industrial Production (1963=100)	Index of Electricity Consumption in Industry (1963=100)
1961	85.1	8.1
1962	89.8	40.3
1963	100.0	100.0
1964	109.9	124.1
1965	119.6	146.5
1966	137.1	219.5
1967	140.6	278.5
1968	150.8	295.6
1969	167.9	322.8
1970	186.2	361.9
1971	204.5	433.5
1972	236.3	483.5
1973	273.7	545.1
1974	268.2	563.0
1975	280.3	637.5

Sources: Statistical Yearbooks of Greece 1971 and 1976; PPC, Organisation Department, Division of Statistics.

be seen in the context of this assumption. But while for the residential and commercial sectors such an assumption seems plausible, for the industrial sector this may well not be the case. An increase in the stock of appliances is, ofcourse, the result of new industrial investment undertaken and hence smooth exponential growth would implicitly suggest a more or less non-violent change in investment decisions. However, due to the nature of investment decisions, the assumption of a smooth exponential growth particularly for the industrial sector is likely to be unrealistic. Hence in periods when the actual rate of growth is below the average growth determined by the regression line, we will tend to interpret the change in quantity demanded as due to changes in the rate of utilisation as approximated by the explanatory factors employed. Conversely, when the actual rate is above the rate determined by the relevant equation we may mistakenly attribute changes in electricity demand as being due to changes in the appliances rate of utilisation. These considerations raise the question of the importance of employing in the analysis actual stock figures about which, for the reasons explained earlier, nothing can be done. What may only be said is that the sensitivity of the results relating to the industrial sector may very well be due to deviations of an unrealistic approximation from reality.

4.6 Long-run Demand for Electricity: Regression Estimates

In this section the estimates of price and "income" elasticities for the residential commercial and industrial sectors are presented in tables 4.18 to 4.20. For the derivation of these estimates 14[1] yearly observations were utilised covering the period 1961-1975. As previously, the ordinary least squares method was used. Nevertheless, in contrast to the formulation relating to short-run demand the set of variables examined, and the mathematical form of the functions were different. It was assumed in other words that in the long-run the price of the main competing fuels (oil) is likely to be a significant factor in influencing consumers' behaviour. The influence of the price of gas on electricity demand has not been considered. Although the studies reviewed suggest that gas as a conpeting fuel may not be disregarded, in the case of Greece the importance of gas has been continuously declining over the years. This decline, resulting in losses that exceeded the amount of 450 million drachmas in 1972, brought up the question of whether the Public Gas Corporation in Athens should continue to operate. The proposal was not ac-

1 One observation is lost because of the presence of the lagged dependent variable. For the residential sector 15 observations were used.

cepted, and drastic steps towards the modernisation of the Corporation were not taken and its decline continued. While at the end of 1962 there were 17,000 customers (mainly in the Athens-Piraeus area) by 1975 this number dropped by 50 percent (8,500).

Moreover, non-economic factors, such as the rate of urbanisation, particularly for the residential sector may increase the explanatory power of the postulated long-run residential demand equation. The influence of substitutes for electricity such as labour (industrial sector) was investigated through the introduction of a variable showing wage earnings over the period under investigation.

The estimated equations for the individual sectors are presented below in tables 4.11 to 4.17.

4.6.1 Long-run Residential Electricity Demand: 1961-1975

Table 4.11

Equation 9: $Q_1 = a_o + a_1(RI) + a_2(RP1) + (1-\lambda_1)(RDL) + v_1$

Explanatory Variables	Parameter	Estimates
1 Constant term	a_o	465.576 (1.552)[1]
2 Real Income (RI)	a_1	9.361 (6.909)
3 Real Relative Price (RP1)	a_2	- 215.956 (3.564)
4 Lagged Residential Demand (RDL)	$(1-\lambda_1)$	.272 (2.289)

R^2	: .997
D-W statistic	: 1.261
r^2 between Independent variables	
$r^2_{(RP1),(RI)}$	: .425
$r^2_{(RP1),(RDL)}$	: .556
$r^2_{(RI),(RDL)}$	: .957

1 The numbers in brackets represent the estimated t-values.

Table 4.12

Equation 10: $Q_1 = a_o + a_1(CE) + a_2(RMP) + (1-\lambda_1)(RDL) + v_1$		
Explanatory Variables	Parameter	Estimates
1. Constant term	a_o	2349.096 (6.443)[1]
2. Current Consumer Expenditure (CE)	a_1	7.354 (5.222)
3. Current Electricity Price (RMP)	a_2	- 222.197 (6.263)
4. Lagged Residential Demand (RDL)	$(1-\lambda_1)$	.441 (3.234)
R^2	:	.997
D-W statistic	:	1.754
r^2 between Independent variables		
$r^2_{(RMP),(CE)}$	;	.750
$r^2_{(RMP),(RDL)}$	:	.493
$r^2_{(CE),(RDL)}$	:	.917

1 The numbers in brackets represent the estimated t-values.

Table 4.13

$$Q_1 = a_0 + a_1(CE) + a_2(RMP) + (1-\lambda_1)(RDL) + a_3(UR) + v_1$$

Equation 11: $Q_1 = a_0 + a_1(CE) + a_2(RMP) + (1-\lambda_1)(RDL) + a_3(UR) + v_1$

Explanatory Variables	Parameter	Estimates
1. Constant term	a_0	- 1533.541 (.5707)[1]
2. Current Consumer Expenditure (CE)	a_1	7.069 (5.215)
3. Current Electricity Price (RMP)	a_2	- 208.790 (5.961)
4. Lagged Residential Demand (RDL)	$(1-\lambda_1)$	.355 (2.496)
5. Urbanisation Rate (UR)	a_3	59.219 (1.457)

R^2	: .997
D-W statistic	: 1.614
r^2 between Independent Variables	
$r^2_{(RMP),(CE)}$	: .750
$r^2_{(RMP),(RDL)}$	: .493
$r^2_{(CE),(RDL)}$	: .917
$r^2_{(RMP),(UR)}$	: .368
$r^2_{(CE),(UR)}$	: .809
$r^2_{(RDL),(UR)}$	: .929

1 The numbers in brackets represent estimated t-values

4.6.2 Long-run Commercial Electricity Demand: 1961-1975

Table 4.14

Equation 12: $Q_2 = b_o + b_1(RGDP) + b_2(RP2) + (1-\lambda_2)(CDL) + v_2$

Explanatory Variables	Parameter	Estimates
1. Constant term	b_o	1146.104 (2.861)[1]
2. Real Gross Domestic Product (RGDP)	b_1	5.031 (6.192)
3. Real Relative Price (RP2)	b_2	- 299.809 (3.795)
4. Lagged Commercial Demand (CDL)	$(1-\lambda_2)$	.386 (3.516)

R^2	: .993
D-W statistic	: 1.941
r^2 between Independent variables	
$r^2_{(RP2),(RGDP)}$	: .536
$r^2_{(RP2),(CDL)}$	: .740
$r^2_{(RGDP),(CDL)}$	: .870

1 The numbers in brackets represent estimated t-values.

4.6.3 Long-run Industrial Electricity Demand: 1961-1975

Table 4.15

Equation 13: $Q_3 = c_o + c_1(IIP) + c_2(IMP) + (1-\lambda_3)(IDL) + c_3(IPO) + v_3$

Explanatory Variables	Parameter	Estimates
1. Constant term	c_o	562.820 (4.361)[1]
2. Index of Industrial Production (IIP)	c_1	8.342 (3.034)
3. Current Electricity Price (IMP)	c_2	- 182.923 (2.971)
4. Lagged Industrial Demand (IDL)	$(1-\lambda_3)$	.668 (4.628)
5. Current Price of Oil (IPO)	c_3	294.597 (2.503)

R^2	: .997
D-W statistic	: 2.008
r^2 between Independent variables	
$r^2_{(IMP),(IIP)}$	: .431
$r^2_{(IMP),(IDL)}$	: .479
$r^2_{(IMP),(IPO)}$	: .960
$r^2_{(IIP),(IDL)}$	: .970
$r^2_{(IIP),(IPO)}$	: .409
$r^2_{(IDL),(IPO)}$	: .432

1 The numbers in brackets represent estimated t-values.

Table 4.16

Equation 14: $Q_3 = c_o + c_1(IIP) + c_2(IMP) + (1-\lambda_3)(IDL) + v_3$

Explanatory Variables	Parameter	Estimates
1. Constant term	c_o	287.618 (3.441)[1]
2. Index of Industrial Production (IIP)	c_1	12.084 (4.238)
3. Current Electricity Price (IMP)	c_2	- 32.535 (1.944)
4. Lagged Industrial Demand (IDL)	$(1-\lambda_3)$	.467 (3.151)

R^2	:	.995
D-W statistic	:	1.950
r^2 between Independent variables		
$r^2_{(IMP),(IIP)}$	:	.431
$r^2_{(IMP),(IDL)}$	:	.479
$r^2_{(IIP),(IDL)}$	:	.970

1 The numbers in brackets represent estimated t-values.

Table 4.17

Equation 15: $Q_3 = c_0 + c_1(IIP) + c_2(IMP) + (1-\lambda_3)(IDL) + c_3(WE) + v_3$		
Explanatory Variables	Parameter	Estimates
1. Constant term	c_0	705.173 (2.875)[1]
2. Index of Industrial Production (IIP)	c_1	8.972 (2.883)
3. Current Electricity Price (IMP)	c_2	- 106.406 (2.420)
4. Lagged Industrial Demand (IDL)	$(1-\lambda_3)$	.403 (2.900)
5. Wage Earnings (WE)	c_3	31.270 (1.790)

R^2	: .996
D-W statistic	; 1.749
r^2 between Independent variables	
$r^2_{(IMP),(WE)}$	: .754
$r^2_{(IIP),(WE)}$	: .872
$r^2_{(IDL),(WE)}$	: .894
$r^2_{(IMP),(IIP)}$	: .431
$r^2_{(IMP),(IDL)}$	: .479
$r^2_{(IIP),(IDL)}$	: .970

1 The numbers in brackets represent estimated t-values.

4.7 Long-run Demand for Electricity: Evaluation of the Estimates

Before going on to evaluate the price and "income" elasticities of the estimated equations one should discuss first the estimates relating to the lagged consumption coefficient. With reference to the latter we have argued that since the two alternative hypotheses give rise to the same estimating equation an identification problem is created. Therefore, on a priori grounds, given the unavailability of information relating to depreciation or scrapping rates of the underlying stocks of electricity consuming appliances, one is not able to decide as to which hypothesis constitutes a better approximation. However, the uniformity of the estimates of the coefficient of the lagged consumption variable seem to provide an answer to this dilemma. As may be seen from the tabulated results the lagged consumption coefficients of the finally selected equations (tables 4.11 to 4.17) imply rates of depreciation ranging from 33.2 percent for the industrial sector (see table 4.15) to 72.8 percent for the residential sector (see table 4.11) which are obviously highly implausible, particularly in the case of a developing country such as Greece. This, assuming that the models postulated are free from probable specification errors, would imply that the data used do not support the "flexible" demand hypothesis which has to be rejected

in favour of the "flow-adjustment" model.
Upon such a consideration the lagged consumption coefficients should be interpreted as providing an estimate of the speed with which actual demand adjusts to desired demand. Acceptance of this interpretation means that the number of periods (years) required to eliminate the existing gap between actual and desired demand may be calculated. However, one may not proceed to such calculations before considering an estimation problem imposed by the presence of the lagged consumption variables in these equations. The presence of a lagged dependent variable in an equation means that "estimation problems and procedures now depend on the assumptions made about the disturbance term"[1].
Upon the simplest possible assumption, namely that the error terms are normally and independently distributed "least squares still seems the best estimating technique"[2]. However, given that we do not know anything about the behaviour of the disturbances in the population we may try to make some inference on the basis of the behaviour of the regression residuals. But presence of lagged dependent variable in the equation renders the validity of the relevant Durbin-Watson statistic questionable. Hence in such cases special estimation proce-

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1 Johnston, J., (1972), p. 304.

2 Johnston, J., (1972), p. 307.

dures would be required. In this study no such complicated methods are used, and this is based on two important considerations. First, the available information used is far from complete and it would be a contradiction to try to fill the gap created by the unavailability of vital information by employing econometric methods that may not be characterised as simple. Second, the main objective of the study is to try to improve our understanding of the influence of economic variables on the demand for electricity rather than to use the electricity market to illustrate complicated mathematical formulations or econometric methods. In order to attempt an answer to the practical questions involved, the simplest statistical technique (that is OLS) was employed in this section as well, and the D-W test[1] was utilised for the detection of autocorrelation[2]. With the previous comments in mind it seems appropriate to start the evaluation of our estimates by considering

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1 With respect to this point Johnston, J. says: "Despite explicit warnings in the original paper that the D-W test is not applicable to an equation containing lagged Y (dependent) values among the explanatory variables it has often been applied, for want of anything better, to such cases". (1972), p. 309.

2 We do not pretend to solve satisfactorily the problem of autocorrelation through the use of the D-W statistic; this statistic is of course biased when lagged endogenous appear in the right hand side, and its use in this study is very tentative.

first the pattern of the regression residuals. As may be seen from tables 4.11 to 4.17 the d-statistic in all but one case (residential demand) is very close to the value of 2.

Consideration of the estimates obtained for the individual sectors suggests the following:

The "Urbanisation rate" variable, (UR), does not seem to contribute considerably in the explanation of variations in total residential electricity demand, equation 11 (table 4.13). An explanation for this may be offered upon consideration of the fact that considerable movements of population from rural to metropolitan areas took place mainly before the period under consideration. The adverse effects of overpopulated urban areas soon appeared in the form of limited job opportunities, accommodation difficulties, increases in the price of housing, severe traffic problems and so on. Hence, while on a priori grounds one would expect that changes in the rate of urbanisation would bring about changes in long-run demand, mainly arising from "demonstration effects" (given that people who move to large metropolitan areas tend to adopt the living standards of those already in them, that is, they tend to try to "keep up with the Joneses") this hypothesis does not seem to be strongly supported by the existing evidence.

Upon such a consideration it would seem that the equations in tables 4.11 and 4.12 are to be preferred. However a choice of which one may constitute a better approximation is rather difficult. The signs of the coefficients of both equations, as well as their statistical significance, are in accordance with a priori expectations. On the other hand the price and activity indicator coefficients, whether the variables are expressed in real terms or in current values, do not differ significantly in absolute terms. A hint of which equation is likely to perform better, however, might be given by the value of the coefficient of the lagged consumption variable, as well as other purely econometric considerations.

As noted above under the "flow-adjustment" hypothesis the coefficient of lagged dependent variable (RDL) gives an estimate of the speed with which actual demand converges towards desired demand. The values of those coefficients imply that in the case of the equation given in table 4.11 approximately 73% (1-0.272=0.728) of the difference is made up during the first period, while the equation in table 4.12 suggests that this rate is equal to about 56%. In turn, the first estimate suggests that over 90% of the gap will be closed in two years time while the second implies that a three year period would be required for the same proportionate adjustment (90%)[1]. Now a comparison between our estimates of the speed of adjustment and those found by Hoythakker and Taylor or those reported by Houthakker, Verleger and Sheehan (see pp. 34 and 37 respectively), suggests that our estimates show a much more rapid adjustment. Of course an obvious explanation would be the differences in structure and other characteristics between the economies (Greece and U.S.A.) where the models have been applied. It is likely, in other words, that very slow adjustment rates (in the neighbourhood of 10% per period) found in the previous studies are due to the important role that natural gas plays in the residential sector. Demand adjustment in a market where the influence of variations in the price of an important competing fuel (such as gas) may be significant (given that such an adjustment would reflect the speed with which consumers make decisions on the basis of the relative prices of competing fuels, the various costs that are involved in replacing, for instance, electricity consuming equipment by appliances using natural gas and so on) may be quite slow. In Greece as has been said previously the importance of gas as a competing fuel is negligible. The other competing fuel, oil, the price of which has been used to deflate electricity price (table 4.11),

1 Note that since complete adjustment never takes place a 90% rather than 100% is taken to imply complete adjustment.

appears to have some influence, as is indirectly manifested by the significance of the relative price coefficient (RP), although oil constitutes an important fuel only in that portion of residential electricity demand relating to heating requirements.

However, another fundamental reason for the considerable difference between our estimates and those mentioned previously may be that while the previous authors interpret their results as showing estimates of adjustment speed, those due to the identification problem discussed in chapter 3, are more likely to give an estimate of the depreciation rate of the underlying stock of electricity equipment rather than of the speed of adjustment between actual and desired demand. Consideration of the estimates on the basis of econometric criteria would tend to favour equation 10 (table 4.12). This is because while the explanatory power of this equation is the same as that of equation 9 (table 4.11), as manifested by the identical value of R^2, the Durbin-Watson statistic of equation 10 might indicate no serious auto correlation. Moreover the degree of collinearity between the most highly correlated variables (activity indicators (RI) or (CE) and lagged demand (RDL)) is lower in the case where consumption expenditure in money terms (CE) is used (equation 10 - table 4.12) rather than in the case where total real income (RI) is employed as an explanatory factor (equation 9 - table 4.11).

Nevertheless, choice of this equation would tend to under-estimate the importance of oil as a substitute for electricity and hence upon such a consideration equation 9 (table 4.11) may be accepted as slightly superior on economic grounds. Now, given that all long-run equations were expressed in linear form the elasticities derived would be different at different levels of the values of the variables included in the equations. Customarily, however, these elasticities are evaluated at the points of the means of the relevant variables. These calculations, performed on the basis of equation 9 (table 4.11), are shown below[1]:

Table 4.18

Residential Sector: Long-run Elasticities (evaluated at the points of means of the regressors of equation 9)

	L.R. Elasticity
Price of Electricity relative to the price of oil (PR1)	- 0.865
Real Income (RI)	1.541

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1 These are based on the formula:

$$\text{L.R Elasticity} = \left[\left(\frac{dX}{dY}\right)\frac{\bar{X}}{\bar{Y}}\right] \div r_i$$

where $\left(\frac{dX}{dY}\right)$ is the coefficient of variable X in the equation, $\bar{X}$ and $\bar{Y}$ are the means of the explanatory factor and the dependent variable respectively and r_i is the estimate of the speed of adjustment between actual and desired demand.

It is interesting to note that the long-run elasticities found for the residential demand are larger (in absolute terms) than those calculated in the short-run formulation (these were - 0.516 for price and 0.602 for income respectively, see page 77 equation 2).
This would mean that as people move towards an equilibrium position, with respect to relative prices, they are likely to become more sensitive to price variations.

Consideration of the estimates relating to commercial electricity demand in the long-run (table 4.14) suggests the following: The degree of multicollinearity between the explanatory factors does not appear to be harmful according to the simple test described in page 86 .
This is especially so for the relative price variable (RP2) (price of electricity relative to the price of oil) and the remaining explanatory variables in equation 13 (table 4.14), that is Real Gross Domestic Product, (RGDP), and lagged commercial demand, (CDL). The value of the Durbin-Watson statistic on the other hand, indicates absence of autocorrelation, while the set of explanatory factors explain, as shown by the value of R^2, more than 99% of the variation in the dependent variable (Q_2).
The signs of all coefficients are in accordance with a priori expectations and they are statistically significant at 5%. The speed of adjustment between actual and desired commercial demand is around 61%, implying a three-year period for complete adjustment (94%) to take

place. The long-run price (RP2) and activity indicator (RGDP) elasticities, calculated as previously (see footnote, page 112) are shown in table 4.19.

Table 4.19

Commercial Sector: Long-run Elasticities (evaluated at the points of means of the regressors of equation 12)

	L.R. Elasticities
Price of Electricity relative to the price of oil (PR2)	- 1.622
Activity Indicator (RGDP)	1.330

The discussion about electricity demand by the industrial sector concentrates on equation 13 (table 4.15) after an elimination process similar to the one adopted when the long-run estimates for residential demand were presented. Accordingly, the degree of multicollinearity was first examined. Although the correlation between the index of industrial production (IIP) and lagged industrial demand (Q_3) appears to be high it is slightly lower than the coefficient of multiple determination R^2. Moreover, it may not provide a means of discrimination among the three differently specified equations given that the collinear variables (IIP and Q_3) as dictated by our long-run formulation, are included in all versions of the idustrial electricity demand equations. Nevertheless, on the basis of the randomness of the residuals, the statistical significance of the coefficients (the (WE) variable in equation 15 - table 4.17, has a lower t-ratio compared to the "price of oil" variable in equation 13 - table 4.15) and the completeness from an economic theory point of view (equation 13 and 15 include prices of substitutes such as oil (IPO) and labour (WE)) the long-run elasticities were evaluated according to the estimated coefficients of equation 13 - table 4.15).

This according to the lagged consumption coefficient shows that the adjustment of industrial demand to changes in economic conditions appears to be fairly slow (33.2% per year), and certainly much lower than that found for the residential (73%) and commercial (61.4%) sectors in the long-run. This comparison reflects the importance of the relative prices of competing fuels, seen in the light of their nature as inputs into distinctly different activities. In both the residential and commercial sectors, given, for technical reasons, the limited opportunity for substitution of electricity by other fuels, users have no other serious alternative but to adjust fairly quickly to the new conditions. In the industrial sector customers have to examine whether price changes are of a relatively temporary nature or are expected to constitute an established new economic reality. Under such an interpretation the period needed for an almost compete adjustment to take place (6 years are required to close 91% of the existing gap between actual and desired demand) seems fairly plausible.

Utilisation of the calculated adjustment coefficient suggests, as the following table shows (table 4.20), that the long-run demand elasticity with respect to electricity price is higher in absolute terms compared to the short-run price elasticity, which is the pattern found for the other two sectors. This may be taken to imply that, in the long-run, as the price of electricity increases the price of industrial output increases as well, ceteris paribus. This causes a decline in the industrial output demanded and the latter results in a decrease of electricity demanded magnifying the response to the initial price increase of electricity. Production shifts towards less electricity intensive processes, as long as the prices of competing inputs are relatively cheaper.

Table 4.20

Industrial Sector: Long-run Elasticities(evaluated at the points of means of the regressors of equation 13)

	L.R. Elasticities
Price of Electricity	- 1.762
Activity Indicator (IIP)	1.119
Industrial price of Oil (IPO)	1.001

4.8 Long-run Demand for Electricity: Conclusions

The long-run analysis deals with the examination of the impact of changes in the price of electricity, the price of the main competing fuels (oil), activity indicators and factors that are thought as significant in a long-run context.

The results suggest that in general the response of demand to electricity price changes is greater (in absolute terms) in the long-run than in the short-run, and this pattern was found to be followed in all sectors. Comparison between sectors suggests the interesting conclusion that in the long-run the industrial sector appears to be more sensitive to price changes than the commercial or residential sector, the last one being fairly insensitive to electricity price changes.[1] The dynamic changes to price increases show, however, exactly the opposite pattern. The element of dynamisation introduced by the inclusion of lagged dependent variables in the long-run equations provide, as explained previously, an estimate of the speed of adjustment of actual to desired demand. Here it appears that residential electricity demand shows the fastest response to price changes (almost 73% per year) compared to commercial demand (61%) and industrial demand which shows fairly slow response (33%). This rather interesting symmetry between long-run price elasticities and speed of response to price changes seems justified upon conside-

1 We may note, however, that these results are strictly not comparable given that the price- variables used are not the same in each equation.

ration of the relative importance of oil as a competing fuel. In the residential sector the possibility of substitution is practically non-existent, apart from that portion of demand associated with heating requirements. The ability of the commercial sector to adapt (though with a lower speed) to relative price changes is manifested in the average long-run price elasticity. Electrical energy use in the industrial sector is controlled by the technical requirements of production, particularly those relating to mechanical functions or electrochemical reactions. Upon such a consideration elasticity may be thought of as consisting of two components: A fixed component which is relatively insensitive to price changes, reflecting the technical requirements of production and a variable component reflecting the intensity of use of electrical energy not for the industrial process itself but for the support of the process in the form of lighting, heating and so on. Moreover, though electricity intensive industrial units dominate the electricity demand in the short-run their small proportion[1] becomes apparent in the long-run examination. Production is governed by industries for which electricity constitutes a more or less variable component. Changes in electricity price and the industrial

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1 See also chapter 1, pages 15-18.

output produced are met by more than proportional changes in the quantity demanded, thus making demand in the industrial sector "price" and "income" elastic. The significance of the price of oil seems to support these conclusions. The empirical evidence that labour fails to be a satisfactory substitute for electricity, as table 4.17 suggests, probably reflects the movement of the industrial sector towards more capital intensive techniques of production using competing fuels.

It should be emphasised, however, as an overall conclusion that unavailability of information relating to appliances - ownership, their prices and technological improvements, does not permit a proper long-run investigation. Changes in prices of fuels, prices of consuming equipment and other factors might lead to structural changes that are not accounted for by the simple approximation made. With this in mind it would be proper to say that the long-run results should be considered as fairly tentative.

4.9 Summary and Conclusions

This study has dealt with the problem of electricity demand in the case of Greece over the period 1961-1975, and with the evaluation of the likely response of demand to changing prices and income in the form of estimated elasticities. An empirical investigation of electricity demand, and indeed of most energy forms, is at the outset associated with some problems due to the nature of the product in question. First, there is a strong technological complementarity between electricity demand and the corresponding stock of electricity consuming appliances which to a great extent governs that demand. A realistic investigation therefore would call for a consideration of some sort of stock of appliances effect.

Now, an immediate distinction between demand in the short-run and demand in the long-run is called for. Such a distinction should not necessarily be made with reference to time, but with reference to the underlying stock of appliances. Short-run demand may be thought of as arising from changes in the utilisation rate of a constant stock. Long-run demand may be defined as that situation where not only the rate of utilisation changes but the stock of appliancces changes as well.
Ideally, a study of the influence of variations in the

rate of utilisation (reflecting changes in the economic environment) on demand would be possible if the investigator could perform controlled experiments by holding all other factors, apart from the utilisation rate, constant. In a desk type of research, however, this is hardly possible. Working with time series data, what one observes is the overall outcome of changes in the rate of utilisation of appliances, the stock of consuming equipment, and technological characteristics of the existing population of appliances. Upon such a consideration a proper way of investigating electricity demand would be to define demand as the product of the average utilisation rate of the stock of appliances, the number of appliances in use and the average technological characteristics (from a consumption of electricity point of view) of the distribution of those appliances. Subsequently changes over time of these three factors could be analysed in terms of changes in relative prices of fuels, relative prices of the various appliances, credit availability, improvements in technology and so on. Nevertheless the requirements for such an approach, datawise, are enormous. In the particular case in hand explicit information relating to the above three factors is totally non-existent. Hence, given (as pointed out above) the necessity to consider some kind of stock - of - appliances effect, and the unavailability of desired information, it appears that the second best solution is the elimination of the stock variable from the demand equation through appropriate assumptions and mathematical manipulations.

Moreover, it is recognised that the assumption of exponential growth of appliances at a constant rate over time may deviate from reality. To the extent that these deviations are substantial, the elasticity estimates as well as the conclusions based upon them may in turn be imprecise. However, there is hardly an alternative solution. The mathematically convenient assumption of constant exponential growth employed for the derivation of short-run elasticities in chapter 3 is the best substitute for approximating reality.

In the absence of desired information relating to the factors mentioned previously (stock of appliances and so on), long-run demand investigation appears even more complicated. Here the finally derived equation to be estimated is consistent with two totally different interpretations. The first formulation (flexible demand assumption) assumes that only flexible demand is sensitive to changes in relative prices and income, while the hypothesis underlying the "flow adjustment" model states that total demand is sensitive to those variables.

An answer to this dilemma is provided by the coefficient of the lagged consumption variable appearing in both formulations. The magnitudes of these coefficients are both low (implying implausibly high scrapping rates of the appliances) and uniform, so as to indicate that the flexible demand hypothesis may safely be rejected in favour of the alternative formulation. This proposition, however implicitly assumes that both formulations are free from other probable specification errors, such as non consideration (because of data limitations) of the likely influence of changes in the prices of appliances, technological improvements and so on. Moreover, changes in the prices of fuels, prices of consuming equipment and other factors, lead to structural changes that cannot be represented within a single equation framework. Thus the long-run results should be considered as fairly tentative.

Second, even if data availability did not impose any serious constraints, investigation of aggregate electricity demand would give rise to a rather serious aggregation problem. Clearly total demand for electricity cannot be considered as homogeneous. In other words, it would be unrealistic to assume that different sectors exhibit identical response patterns to changes in relative prices and activity indicators.

It is fortunate that this restrictive assumption is avoided through utilisation of unpublished information relating mainly to yearly consumption and electricity prices applicable to the household, commercial and industrial sectors. Such a disaggregation provides an indication as to which sectors are likely to be able to cope with increasing electricity prices and which sectors do not exhibit such flexibility.

In the light of the above remarks it appears that if conclusions and appropriate actions were to be based on the short-run estimates they would indicate that attention should be focused on measures aiming at reducing the dependence of the electricity market on oil imports. For, if as the estimates obtained suggest, proportionate increases in electricity prices (such as those experienced during the period 1961-1975) are unable to cause an equiproportionate decrease in electricity demand, the associated rate of growth of oil imports for electricity generation requirements is unlikely to decline significantly (see table 1.1, page 9). Thus it seems that a way to secure uninterrupted economic growth and development would be the introduction of measures aiming at a more intensive utilisation of indigenous energy sources such as water-power and lignite.

However, the orientation of electricity generation towards utilisation of indigenous energy inputs (such as lignite and water-power) is not an easy matter to deal with. Although it would seem that satisfaction of a continuously increasing electricity demand could be achieved through the construction of electricity generating stations based exclusively on indigenous energy sources, thus minimising the risk of depending upon imported fuels, it should be stressed that :

1. As far as lignite is concerned the known reserves are not expected to last for more than 35 to 40 years[1]. This consideration, in conjuction with the fact that lignite is used for other industrial and to a smaller extent domestic purposes, dictates that the relative costs and benefits of such a policy proposal should be examined and evaluated carefully.

2. The water-power potential of the country is undoubtedly considerable, and it has been suggested that exploitation of it under "reasonable" cost conditions could produce electricity of the order of 20 billion kwh/year[2]. Nevertheless, the construction of additional water-power generating stations had in the past been delayed and the argument was that construction costs were high while the electricity producing efficiency of those stations was relatively low. The dramatic increases of oil prices after 1973, as well as the view that oil price increases are likely to continue in the future, point to the conclusion that the exploitation of the country's water potential does not appear any more as a remote economic reality. This view may be strengthened upon consideration of the fact that water-power may not only be taken into account in electricity generating projects but in other vital de-

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1 "Report on the Energy Policy in Greece", (1976), p. 21.

2 See also Appendix 1, pp. 142-143.

velopment projects such as irregation or improvements of water supply systems.

Whether such implications, suggested by empirical evidence based on information which is considered far from ideal, are justified should be the subject of further scientific research.

Appendix 1

Energy in Greece: An Overall View

In this Appendix a brief discussion concerning the overall energy market in Greece is presented. This, it is believed, will reinforce our analysis on the demand for electricity and it will provide more evidence in support of the importance of electricity for the economic development and prosperity of the country.

The main target of every developing country, such as Greece, is the modernisation and industrialisation of its economy[1]. Given the apparent interdependence between energy and economic growth, however, achievement of such a target requires a rapid growth of the energy sector. Energy is a necessity for many modern industrial processes which involve chemical transformation. The manufacture of cement or steel, for example, both require great quantities of heat. In addition, for certain leading industries energy is necessary as a basic "feedstock"; in other words the energy source itself becomes part of the final product. In the manufacture of pig iron or petrochemicals, for instance, the hydrocarbons in coal and oil are incorporated bodily.

Finally, energy is an irreplaceable element of final consumer demand, for example of household cooking,

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1 See Organisation for Economic Co-operation and Development (1971-72), Centre of Planning and Economic Research (1968) and Ministry of Co-ordination (1968).

heating, transportation and lighting. The qualitative role of energy as a necessary element for physical production has been stressed by some economists. According to a study prepared by the United Nations: "Although in many cases the cost of energy, especially of electricity, represents but a minor percentage of total costs, energy exercises great influence because of its qualitative effects. It is the key element without which the production process cannot operate adequately, and the lack or shortage of energy may cause serious difficulties. It stands in the same position as other tangible or intangible factors of industrial production, the economic effects of which are more important than their net cost"[1].

The quantitative impact of energy on key sectors of the economy is even more considerable. This is because, particularly in the case of Greece, the pattern of economic development is one of relatively rapid industrial growth and relatively stagnant agricultural production; whatever the underlying reasons, the advance in the idustrial sector has important implications for the energy sector, because the energy input per unit of output is generally far higher in industry than in agriculture. On the other hand energy is much

1 United Nations, (1957), p. 4.

more significant in the modern heavy industries (advanced industries) than in the traditional industries (backward industries).

While the above considerations reinforce the importance of energy in the economy's function and performance, the dramatic increase in crude oil prices towards the end of 1973 shook the economy to its very foundations and added new dimensions to the already existing economic and energy problems of the country, whose economic and industrial prosperity has been largely based on the cheap and abundant supply of energy products and especially on the supply of oil[1].

"Since September 1973 the cost of oil supplies has increased fourfold with severe effects on the balance of payments. In 1974 the amount of foreign exchange (in current prices) spent on imports of petroleum and petroleum products was $ 860 million compared with $ 387 million in 1973, $ 93 million in 1970 and $ 44 million in 1960; the increase between 1973 and 1974 being 115 percent. The foreign exchange spent on petroleum imports in 1974 accounted for about 19 percent of the country's imports bill. The general price level has also been affected considerably. The direct ef-

1 See also Catziargiris, K., (1971).

fect of the rise in oil prices on the wholesale price index was estimated at about 7 percent in 1973. But probably even more significant must have been the indirect effect of this increase on the domestic price level through its impact on production costs, given that 25 percent of the total quantity of liquid fuels is consumed by industry, 41 percent by transport and 25 percent by electricity generating stations"[1].

Energy consumption in Greece has increased rapidly from 1.6 million metric tons of oil equivalent in 1960 to 7.5 million tons in 1975. This means that energy consumption has increased at an average annual rate of 11.5 percent compared with an increase of 7.5 percent of Gross National Income in real terms[2]. Despite the relatively high growth in energy consumption however, the per capita energy consumption is only 1/3 of that in the EEC countries and 1/6 of that in the USA, on the basis of information relating to 1976. As far as the composition of energy is concerned, in 1975 about 71.5 percent of the total consumption of primary energy sources was accounted for by liquid fuels, 24 percent by solid fuels and the balance of 4.5 percent by other sources (mainly waterpower)[3].

1 Zolotas, X., (1975), pp. 10-14.

2 National Energy Counsil, (1976).

3 Efthymoglou, P.G., (1969).

In terms of final energy forms, 15.6 percent of total consumption in 1975 was accounted for by electricity, 74.2 percent by petroleum products and 10.2 percent by solid fuels (tables 1 and 2). The absence in the final consumption of natural gases, justifies the dominant share of petroleum products in the consumption of energy, despite the fact that this share has been decreasing (as table 2 shows) from 79.9 percent in 1960 to 74.2 percent in 1975[1]. On the other hand the consumption of electricity has increased by 50 percent during the period 1961-1975. Finally, the consumption of solid fuels appeared to be steadily rising through the 1960-75 period, suggesting that chemicals as well as other basic industries have been developing in the country.

As far as energy consumption by different economic sectors is concerned the situation in 1975 was as table 3 shows.

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1 National Energy Counsil, (1976).

Table 1

Energy Consumption Patterns in Greece

(10^3 tons of oil equivalent)

Year	Electricity	Oil Products	Solid Fuels	Total
1960	164	1300	765	1629
1961	180	1430	186	1796
1962	203	1520	173	1896
1963	230	1656	241	2127
1964	276	2166	278	2720
1965	321	2406	341	3068
1966	427	2610	422	3459
1967	514	2991	382	2887
1968	557	3238	295	4190
1969	639	3689	455	4783
1970	719	4024	538	5281
1971	845	4660	420	5925
1972	962	5223	555	6740
1973	1092	5823	687	7602
1974	1105	5288	703	7096
1975	1167	5560	765	7492

Sources: Ministry of Industry and Ministry of Co-ordination, Unpublished Data.

Table 2

Energy Consumption Patterns in Greece

(Percentage)

	Selected Years		
	1960	1970	1975
Primary Energy Inputs			
Liquid fuels	77	73.3	71.5
Solid fuels	17.8	16.9	24.0
Hydroelectricity	5.2	9.8	4.5
Final Energy Consumption			
Electricity	10.0	13.5	15.6
Oil products	79.9	76.0	74.2
Solid fuels	10.0	10.5	10.2

Sources: PPC, Ministry of Co-ordination and Ministry of Industry. Unpublished Data.

Table 3

Analysis of Total Energy Consumed by Different Economic Sectors (in 10^3 tons oil equivalent)

Year	Sectors									
	Industry		Transportation		Agriculture		Residential		Others	
		%		%		%		%		%
1960	506	31.1	507	31.1	158	9.7	350	21.5	105	6.4
1961	616	34.3	537	29.9	162	9.0	371	20.7	106	5.9
1962	730	38.5	497	26.2	165	8.7	409	21.6	90	4.7
1963	866	40.7	546	25.7	170	8.0	440	20.7	100	4.7
1964	1072	39.4	626	23.0	260	9.5	583	21.4	176	6.5
1965	1278	41.6	655	21.3	294	9.6	628	20.5	209	6.8
1966	1594	46.1	737	21.3	336	9.7	632	18.3	158	4.6
1967	1645	42.3	799	20.5	374	9.6	802	20.6	264	6.8
1968	1726	41.2	830	19.8	462	11.0	906	21.6	264	6.3
1969	1997	41.7	940	19.6	481	10.0	1013	21.2	364	7.2
1970	2313	43.8	1084	20.5	503	9.5	1048	19.8	329	6.2
1971	2572	43.4	1212	20.4	544	9.2	1213	20.5	384	6.5
1972	2945	43.7	1442	21.4	585	8.7	1365	20.3	403	6.0
1973	3400	44.7	1614	21.2	631	8.3	1627	21.4	330	4.3
1974	3443	48.5	1309	18.4	685	9.6	1354	19.1	305	4.3
1975	3412	45.5	1423	19.0	687	9.2	1467	19.6	503	6.7

Source: Center of Planning and Economic Research.

The main characteristic of the composition of energy consumption by the different economic sectors, as table 3 shows, is the increasing share of the industrial sector and the decreasing one of the transport sector. More specifically, between the years 1960 and 1965 the share in consumption of the industrial sector increased by 10.5 percent due to the establishment of new energy (electricity) intensive industrial units such as ESSO-PAPPAS, Aluminium and Chemical Fertilizers. From 1965 to 1975 the changes in the proportions are not as high, but again the industrial sector increased its participation from 42 to 46 percent against a very small decrease in the participation of the other sectors.

Finally, table 4 gives some ideas and comparisons concerning the proportion of participation of different liquid fuels used by the Greek economy as well as by the economies of the EEC and the USA respectively, in the selected year 1973.

Table 4

Participation of Different Types of Liquid Fuels used in the Consumption of Energy (1973), (percentage)

Liquid Fuels	Greece	EEC	USA
Gasoline	17.2	21.5	57.5
Kerasene	0.9	2.3	2.3
Diesel oil	40.6	12.2	10.1
Mazout oil	39.7	63.8	29.5
Others	1.6	0.2	0.8

Source: Centre of Planning and Economic Research.

The main features of table 4 are: First the very low proportion of gasoline consumed in Greece compared with the EEC countries and particularly with the USA where gasoline is almost the only form of energy used in transport, and second that of the high consumption patterns which diesel oil exhibits in Greece. The above trends can be understood better if one considers the multiple uses of diesel oil and the fact that the transport sector is not as advanced in Greece as it is in the EEC countries and especially in the USA.

The conclusions that emerge from the above mentioned trends may be summarised as follows:

1. The faster growth rate of industry and particularly of heavy industry, such as chemicals and metal industries, compared with agriculture, and the increasing standards of living of the population, have helped make the energy sector a rapidly growing and increasingly crucial area of the Greek economy. As a result of the overall economic development the energy consumed by all sectors has increased by 1.6 as fast as national income during the period 1969-1975.

2. The Greek economy is heavily dependent on imported fuels. This is evident from the high proportion of liquid fuels - all of which are imported - in total energy consumption (table 2). The internal energy sources appear to possess a mixture of positive and negative characteristics. For instance, there are significant quantities of lignite in many parts of the country but

its thermal capacity is quite low. On the other hand, waterpower requires large amounts of capital and time in order to be transformed into useful forms of energy so any large scale project based on it to be uneconomic. Nevertheless, considering the effects of the increase in crude oil prices on the country's economy, the utilisation of the internally available energy sources can lead to substitution for the imported crude oil without the process of the industrialisation and economic development of the country being dangerously affected.

The indigenous energy sources are the following:

1. Lignite: Proved reserves of lignite exist in more than fifty different parts of Greece amounting to about 4,000 million tons; there are indications, however, that the country's total reserves are actually more than one billion tons. Though the existing quantity of lignite is quite large, its thermal ability is not so high, varying between 1,050 kcal/kg in Megalopolis to 3,200 kcal/kg in Alivery.

From an economic point of view the reserves possess two characteristics. First, they are near the surface so the cost of their recovery is not high; and secondly, they are geographically concentrated in specific areas. Ptolemays, Megalopolis and Alivery are the main lignite centres, producing 98 percent of the total production of the country. The remaining 2 percent being produced in small places spread all over Greece. During the period 1974 to 1976 the new by discovered reserves amounted to

660 million tons. Of these, 450 million tons are in Ptolemays, 65 million tons in Megalopolis and the rest, (145 million tons) in other places.

In 1974 and 1975 the production in Megalopolis was 4.4 and 9 million tons respectively. In Ptolemays, on the other hand, the lignite production amounted to 6.9 million tons in 1974 and 16 million tons in 1975. It has been estimated[1] that with the intensity of today's use, Megalopolis' reserves will last until 2010, Ptolemays' until 2018 and Alivery's reserves up to 1985.

The largest part, 85 percent, of the total quantity of lignite consumed in Greece is used for electricity generation; The remaining 15 percent is used in Industry by large industrial units such as LARKO (500 thousand tons per year) and the Chemical Industry AEBAL producing fertilizers.

The following tables (tables 5 and 6) represent the production and consumption patterns of lignite in Greece respectively during the period 1960 - 1974.

1 PPC Division of Statistics.

Table 5.

Lignite Production in Greece

(in 10^3 metric tons)

Year	Small Mines	Alivery	Ptolemays	Megalopolis
1960	418	766	1378	-
1961	391	726	1385	-
1962	395	710	1595	-
1963	385	816	2439	-
1964	375	780	2816	-
1965	365	671	4172	-
1966	355	602	4115	-
1967	345	611	4318	-
1968	335	529	4866	-
1969	325	440	6069	-
1970	310	537	6145	957
1971	295	590	6094	4100
1972	280	505	6490	4410
1973	265	552	7760	4500
1974	250	525	8840	4400

Source: A. Diabolitsis, (1975), page 33, table 4

Table 6

Lignite Consumption in Greece

(in 10^3 metric tons)

Year	Electricity Generation	Production of Briquetes	Consumption by the Industrial Sector
1960	1779	208	227
1961	1998	152	193
1962	2245	178	128
1963	2723	312	132
1964	3016	353	183
1965	3759	395	379
1966	3869	271	701
1967	3974	411	816
1968	4372	422	911
1969	5542	363	879
1970	6591	411	832
1971	9318	259	1176
1972	9124	541	1261
1973	11200	732	1353
1974	11700	774	1615

Source: OECD, Energy Statistics, 1959-1973 and for the years 1973 and 1974, PPC, Statistical Division.

2. Peat: Peat deposits at Philippi cover an area of 40 thousand hectares and are estimated at 4,000 million metric tons. According to a study concerning the use of peat for electricity generation the quantity to be extracted would amount to only 7.5 percent of the total peat reserves at Philippi in an area of around 4,400 hectares.[1] This quantity, however, would be enough to supply three thermoelectric plants of 120 MW each for a period of fifteen years. The total generating capacity of these stations would increase the PPC's installed capacity by about 11 percent above its 1973 level. Peat can be extracted by methods similar to opencast mining which imply favourable extraction costs. In fact it has been estimated that the cost of a calorie obtained from peat would be 20 to 30 percent less than the cost of a calorie from lignite at Ptolemays and Megalopolis.[2] Nevertheless, in a recent publication by the Ministry of Co-ordination's, Energy Council, it is pointed out that in the near future, peat is not going to be used as a form of energy because of the high social costs involved in its recovery[3].

3. Waterpower: In the present stage of economic development hydroelectric projects with irrigation and

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1 and 2 PPC, Division of Statistics.

3 Ministry of Co-ordination, (1976), p. 23.

flood control are very important for the country. The PPC estimates the country's potential waterpower at 84.6 million MWH per year while exploitable waterpower is estimated at 20 million MWH per year of which only 3.3 million MWH annually, or about 16 percent, is currently being utilised for the generation of electricity. According to the Corporation's program, about 40 percent of the country's exploitable waterpower is going to be utilised by 1985. It must be noted, however, that hydroelectric stations are generally operated to cope with peak loads. Waterpower then can be utilised in conjunction with baseload stations making use of other energy sources, for example, lignite.

4. <u>Petroleum</u>: Since 1920 there were indications of the existence of petroleum deposits in different parts of the country, but only recently, at the beginning of 1974, have the discoveries off the cost of Thasos made a significant addition to the country's known energy sources. It is estimated that within two years the crude oil output could have reached 50 thousand barrels a day, which is around one third of domestic requirements. Unfortunately, three years have now elapsed without the production of oil taking place. The reasons are both technical and political: Technical, in the sense that the Oceanic Exploration Co. which undertook the research and made the discoveries of oil deposits went bankrupt and this brought about a halt to the work in the area for

a considerable period. In the meantime, and after a period of seven years of political instability, democracy was restored again and this brought a reconsideration of energy policy issues. Nowadays the Public Petroleum Enterprise, in conjunction with some American and French companies, are engaged in the task of research and exploration of petroleum deposits existing in Greece.

3. As tables 1 and 2 show, within the distribution of final energy consumption the share of electricity has been increasing over the years. This probably reflects the economy's orientation towards a more efficient energy product for the production of which utilisation of indigenous energy sources is possible.

Appendix 2

Alternative Formulations of the Estimated Equations

Short-run Residential Electricity Demand: 1961-1975

Table 1

Equation: $\Delta \ln q_1 = \delta_1 + a_1 \Delta \ln(MIPC) + a_2 \Delta \ln(RMP) + a_3 \Delta \ln CPI) +$

Explanatory Variables	Parameter	Estimates-Elasticities
1. Constant term	δ_1	0.036 (4.012)[1]
2. Current Disposable Income per customer (MIPC)	a_1	0.584 (4.199)
3. Current Price of Electricity (RMP)	a_2	- 0.523 (3.129)
4. Consumer Price Index (CPI)	a_3	- 0.108 (0.402)

R^2	:	.861
D-W statistic	:	2.143
r^2 between Independent Variables		
$r^2_{(RMP),(MIPC)}$	:	.263
$r^2_{(RMP),(CPI)}$	:	.759
$r^2_{(MIPC),(CPI)}$	:	.608

1 The numbers in brackets represent estimated t-values.

Short-run Commercial Electricity Demand: 1961 - 1975

Table 2

Equation: $\Delta \ln q_2 = \delta_2 + b_1 \Delta \ln(GP/C) + b_2 \Delta \ln(CMP) + b_3 \Delta \ln(WPI) + u_2$

Explanatory Variables	Parameter	Estimates-Elasticities
1. Constant term	δ_2	0.012 (0.577)[1]
2. Current Gross Domestic Product per customer (GP/C)	b_1	0.492 (1.306)
3. Current Price of Electricity (CMP)	b_2	- 0.987 (3.262)
4. Wholosale Price Index (WPI)	b_3	0.467 (1.091)

R^2	:	.592
D-W statistic	:	2.150
r^2 between Independent Variables		
$r^2_{(CMP),(GP/C)}$	:	.328
$r^2_{(CMP),(WPI)}$	:	.656
$r^2_{(GP/C),(WPI)}$	:	.621

1 The numbers in brackets represent estimated t-values

Appendix 3

Data and Sources

Residential Electricity

Year	Consumption of Electricity in MWH (thousand) (Q_1) (1)	Money Price of Electricity Dr/10 KWH (RMP) (2)	Number of Customers tens of thousand (C) (3)	Money Personal Disposable Income Current prices billion (MI) (4)	Money National Private Consumption Expenditure current prices billion (CE) (5)	Consumer Price Index (1970=100) (CPI) (6)
1961	615.09	11.80	88.39	99.99	87.40	0.83
1962	701.84	12.02	98.71	106.00	94.39	0.83
1963	815.49	11.58	109.46	118.12	102.65	0.85
1964	945.14	11.62	120.08	131.65	111.58	0.86
1965	1082.59	11.56	135.18	149.21	128.14	0.88
1966	1244.31	11.45	151.08	162.85	139.88	0.93
1967	1400.36	11.51	173.34	177.28	150.29	0.94
1968	1519.06	12.13	193.99	189.23	160.46	0.95
1969	1772.92	11.83	210.92	208.69	175.23	0.97
1970	1990.39	11.77	227.97	231.56	201.38	1.00
1971	2290.69	11.49	243.50	258.64	221.60	1.03
1972	2676.53	11.55	257.48	307.46	250.29	1.08
1973	3070.19	12.37	272.39	394.24	312.72	1.25
1974	3001.75	16.27	283.44	468.44	407.89	1.58
1975	3339.92	17.76	294.62	536.95	484.68	1.80

Residential Electricity

Year	Money Price of Crude oil Dr/litro (RPO) (7)	Population Million (P) (8)	Urbanisation Rate Inhabitants per square km (UR) (9)
1961	2.19	8.398	63.6
1962	2.19	8.448	64.0
1963	2.19	8.478	64.2
1964	2.19	8.510	64.5
1965	2.19	8.550	64.8
1966	2.19	8.614	65.3
1967	2.19	8.716	66.0
1968	2.19	8.741	66.2
1969	2.19	8.773	66.5
1970	2.19	8.793	66.6
1971	2.20	8.831	66.9
1972	2.20	8.889	67.3
1973	2.60	8.929	67.6
1974	3.50	8.962	67.9
1975	4.76	9.047	68.5

Residential Electricity

Sources of Data: 1961 - 1975

Column(s)		Sources
(1),(2),(3)	:	Public Power Corporation, Division of Statistics.
(4)	:	Ministry of Co-ordination, (1973),National Accounts of Greece, Table 17, pp. 104-105 Ministry of Co-ordination, (1976),National Accounts of Greece, Table 13, p. 28.
(5)	:	Ministry of Co-ordination, (1973),National Accounts of Greece, Table 11, pp. 92-93 Ministry of Co-ordination,(1976),National Accounts of Greece, Table 5, p.19.
(6)	:	Statistical Yearbooks of Greece: 1971, table XXII:3 p.339 and 1975, table XXI:3 p. 423.
(7)	:	Center of Planning and Economic Research.
(8),(9)	:	Statistical Yearbook of Greece, 1975, table II:3, p. 17.

Commercial Electricity

Year	Consumption of Electricity (thousand) (Q_2) (1)	Money Price of Electricity DR/10 KWH (CMP) (2)	Number of Customers tens of thousand (C) (3)	Money GDP in Current Prices billion (GDP) (4)	Wholesale Price Index 1970=100 (WPI) (5)	Money Price of Crude Oil DR/litro (CPO) (6)
1961	523.89	10.68	23.70	105.18	0.81	2.19
1962	592.71	10.75	24.98	111.33	0.81	2.19
1963	672.98	10.58	28.34	122.64	0.85	2.19
1964	776.42	10.45	29.51	136.95	0.88	2.19
1965	875.71	10.47	33.55	154.06	0.89	2.19
1966	1022.34	10.33	36.21	169.02	0.92	2.19
1967	987.53	10.53	38.85	182.61	0.93	2.19
1968	969.19	11.22	42.24	196.79	0.93	2.19
1969	1301.89	10.51	47.98	220.20	0.96	2.19
1970	1480.53	10.48	51.41	246.97	1.00	2.19
1971	1678.19	9.92	54.28	274.90	1.04	2.20
1972	1983.16	9.76	56.65	326.88	1.10	2.20
1973	2271.38	10.63	59.70	423.07	1.35	2.60
1974	2243.91	14.49	62.12	517.21	1.86	3.50
1975	2444.02	16.24	65.50	597.20	1.98	4.76

Commercial Electricity

Sources of Data: 1961 - 1975

Column(s)	Sources
(1),(2),(3)	: Public Power Corporation, Division of Statistics.
(4)	: Ministry of Co-ordination (1973), National Accounts of Greece:1958-1972, Table 1, pp. 54-55; and National Accounts of Greece:1975, Table 1, p.9.
(5)	: Statistical Yearbook of Greece 1971, Table XXII:2, p. 338; and Statistical Yearbook of Greece 1975, Table XXI:2, p. 422.
(6)	: Centre of Planning and Economic Research.

Industrial Electricity

Year	Consumption of Electricity in MWH (thousand) (Q_3) (1)	Money Price of Electricity Dr/10 KWH (IMP) (2)	Number of Customers tens of thousand (C) (3)	Index of Industrial Production 1970=100 (IIP) (4)	Money Price of Crude Oil Dr/litro (IPO) (5)	Per day Wage Earnings (average M+F) Drachmas, Current (WE) (6)
1961	954.06	6.17	31.08	0.457	2.03	61.04
1962	1060.84	6.24	33.51	0.482	2.13	63.84
1963	1185.09	6.17	36.87	0.537	2.13	67.36
1964	1325.17	6.18	40.23	0.590	2.13	74.64
1965	1521.53	6.17	45.11	0.642	2.13	81.04
1966	1730.85	6.13	56.18	0.736	2.13	91.20
1967	1851.35	6.37	76.40	0.755	2.13	101.92
1968	1976.88	6.53	85.02	0.810	2.13	109.36
1969	2066.65	6.08	63.97	0.902	2.13	120.48
1970	2271.57	6.00	66.06	1.000	2.07	127.60
1971	2495.38	6.11	69.79	1.098	2.07	138.80
1972	2757.34	6.14	77.44	1.269	2.07	151.52
1973	3138.54	6.81	81.74	1.470	2.45	176.32
1974	3071.29	9.45	109.28	1.440	3.31	222.72
1975	3269.32	10.64	115.36	1.505	4.53	277.60

Industrial Electricity

Sources of Data: 1961 - 1975

Column(s)		Sources
(1),(2),(3)	:	Public Power Corporation, Division of Statistics.
(4)	:	Statistical Yearbooks of Greece, 1972, table X:8, p. 203 and 1975, table X:11, p. 233 respectively.
(5)	:	Center of Planning and Economic Research.
(6)	:	Society of Geek Manufactures, The Greek Industry, Annual Reports, different issues.

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