Industrial Demand for Energy in New South Wales: A Micro-Econometric Study

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A micro-econometric study of the industrial demand for energy in NSW

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by

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Executive summary

- This report presents a detailed econometric analysis of data from the NSW Census of Manufacturing over the period 1977/78 to 1984/85. The econometric analysis made use of observations on the variables used at the level of the establishment, in contrast to most econometric studies that use data aggregated to the 2-digit industry level.

- The objective of the study is to provide an econometric analysis of the demands by manufacturing establishments for coal, oil, gas and electricity. The relationships between the industrial demands for these forms of energy on the one hand, and the input prices faced by producers and the levels of output produced on the other are estimated.

- The industrial demand for energy has changed dramatically during the 8-year period from 1977/78 to 1984/85. The use of gas in NSW manufacturing has increased five-fold, while the use of oil has declined to one-tenth of its initial level. Compared to these dramatic changes, the use of other fuels has remained reasonably constant, with coal declining and electricity increasing in importance.

- The prices of the four different forms of energy considered in this project have also altered significantly over this period. The price of oil increased five-fold over the 1977/78-1984/85 period. The other fuel prices less than doubled over this period thus creating a big change in the relative price of oil. Of the other forms of energy gas had the lowest rate of price increase of about 76 per cent,

followed by electricity with about 85 per cent, and coal with about a 99 percentage increase.

- These price changes have been important explanations of the changes in the quantities of coal, oil, gas and electricity that have been observed.

- The own-price elasticities of demand for oil, gas and electricity are generally above one in absolute value indicating elastic demands. This means that an increase in the price causes a more than proportionate fall in the quantity demanded so that expenditure on the item falls.

- For electricity the elasticity (in Model A) is in the range -1.2 to -1.4, indicating that a 10 per cent increase in the price of electricity will cause a 12 to 14 per cent fall in the demand for electricity.

  The own-price elasticities for gas and oil are more variable over industry subdivisions and vary from about -1.2 to -2.3.

- The own-price elasticity for coal is generally lower than unity in absolute value as are the own-price elasticities for labour and capital. These inputs, therefore, have inelastic demands.

- The effects upon demands of changes in output and time are less well estimated and are generally small in size.

- There are significant differences in the technologies of establishments over (i) industry subdivisions within the NSW manufacturing sector, and (ii) different patterns of fuel usage.

- The report indicates that the results obtained in this study may be used to help provide forecasts of future energy demands, conditional upon having information or forecasts of future output levels and input prices.

Contents

List of Tables

List of Figures

1. Introduction

This report is primarily concerned with an econometric analysis of the rather extensive data set consisting of observations on all manufacturing establishments in New South Wales (NSW) over an 8-year period and drawn from the Australian Bureau of Statistics' (ABS) Census of Manufacturing Establishments. While published statistics from these censuses have been available for many years, such aggregate statistics necessarily lose a lot of the valuable information relating to individual establishments. To overcome this loss of information the NSW Department of Energy obtained an agreement with the ABS to provide computing and manpower resources to access and to undertake detailed statistical analysis of data from these surveys, the basic unit of observation actually used in the statistical analysis being the establishment. As a result, the data set employed directly in the statistical analysis consisted of about 10,000 manufacturing establishments per year for the 8-year period 1977/78 to 1984/85. Access to such a large number of observations on a fairly comprehensive and detailed set of variables provides an unusually good opportunity for econometric analysis.

The focus of the project is on the determinants of the demands by manufacturing establishments for different forms of energy, which, for the purpose of this project, are defined to be coal, oil, gas and electricity. The data set has extensive but incomplete information on the use of these fuels by manufacturing establishments. Additionally, the surveys also requested information on labour inputs, investment, and outputs. These data are used as inputs to the estimation of an econometric model of the demands for the four fuels and the other inputs. The results of such an estimation may be used to evaluate the responsiveness of the demands for the different fuels to changes in exogenous variables, such as the prices of the various fuels, the wage rate, the rental rate on capital, the level of output, and the passage of time. The responsiveness of demands to the exogenous variables is usually measured in the form of an elasticity. The results may also be used to provide an important part of the information needed to construct forecasts of future energy demands.

Interest of economists, policy makers and managers in the study of the demand by the production and household sectors for energy was sparked in the mid 1970's by the so called "oil crisis". Of particular interest were the questions of whether supplies of non-renewable energy forms were running out, whether alternative forms of energy or technological advances would arise to alleviate the problem, and whether the national economies of the world could adjust to a changing price structure for energy. Many empirical studies arose from these concerns. One class of such studies relates to the determinants of the demands by the production sector for energy forms. Drawing upon the economic theory of the firm, various researchers used available economic data to estimate the responsiveness of demands for energy to changes in the relative prices of alternative forms of energy, to changes in the price of energy relative to other inputs, to changes in the structure of industrial outputs, and to technological change.

More recently, interest in the demand for energy has continued and grown as a result of the need by government authorities and private businesses to plan for the future. There is an intricate relationship between the markets for energy on the one hand and the industrial structure of the production section of the economy on the other. Changes in either the market for energy or the industrial structure have important effects upon the other, and a study of the demands for different forms of energy is a necessary component to the understanding of this relationship. Moreover, there is a need within the energy production sector for an appreciation of the responsiveness of demands for alternative forms of energy to changing relative prices for energy and other inputs. In short, interest has shifted towards obtaining a better understanding of the market behaviour, consumer price responses and major determinants of energy end-use, all of which have been critical to the effectiveness of planning by utilities and their commercial viability. For these reasons research into the industrial demands for energy is an important and interesting task.

All of the published research of which I am currently aware makes use of aggregated data. Typically these data are averages of variables over various industries. These studies usually examine either substitution possibilities between energy forms or substitution between energy (as an aggregate) and other inputs such as labour and capital.

Among the studies of substitution between various forms of energy are Magnus and Woodland [1987], Pindyck [1979], Griffin [1977], Fuss [1977], Halvorsen [1976] and Hall [1983]. Magnus and Woodland used time series data on six different manufacturing industries in the Netherlands. Griffin used data for twenty OECD nations over five different years. Pindyck and Hall similarly used time series data on several nations in their studies. Fuss used time series data for five regions of Canada. Finally, Halvorsen bases his study on data from the US Census of Manufacturers but it is aggregated to the 2-digit industry level.

In all of these (and other) studies the aggregate nature of the data leads to two particular difficulties. First, the aggregation prevents the use of establishment level data directly in models that are designed to be applied at the establishment or firm level. Second, the prices used are necessarily <u>average</u> prices, when the economic theory of cost minimization recognizes that the appropriate price to be using as an explanatory variable is the <u>marginal</u> price for energy forms such as electricity and gas, which are usually sold according to a declining block schedule. An exception to the use of average prices is Halvorsen [1976].

The same general comments apply to studies of the substitution between energy (as an aggregate or composite factor) and other inputs such as materials, labour and capital. Such studies include Magnus [1979] using aggregate time series data for the Netherlands, Pindyck and Rotemberg [1983] and Berndt and Wood [1975] using aggregate time series data for US manufacturing, Westoby and McGuire [1984] using time series data for the UK electricity industry, and Griffin and Gregory [1976] using time series data for nine industrial countries.

Only a few of the many studies of the demand for energy have been listed above. For more complete surveys, see the surveys of econometric studies of energy demand behaviour by Bohi and Zimmerman [1984] and Donnelly [1987].

Studies in the Australian context have followed the overseas pattern in using aggregated data. The main published studies are by Duncan and Binswanger [1976], Hawkins [1977] [1978] and Turnovsky, Folie and Ulph [1982]. Bartels [1986] surveys these contributions. Duncan and Binswanger examine the substitution possibilities between four energy types using time series data for the period 1948/49 to 1966/67 on 16 Australian manufacturing industries. Hawkins deals with labour, capital and three energy types (gas and electricity are aggregated) using data on individual manufacturing industries in Australia over the period 1949/50 to 1967/68. Turnovsky, Folie and Ulph estimate a model containing capital, labour, energy and materials as inputs, with energy split into four categories, for the Australian manufacturing sector over the period 1946/47 to 1974/75.

Turnovsky and Donnelly [1984] [198?] estimate two-stage models for the Australian iron and steel industry (ASIC subdivision 2941) using data for the period 1946/47 to 1978/79 and for the Australian manufacturing sector for the same period. More recently, Bartels [1984] estimates a set of share equations for the various forms of energy for the six 2-digit ASIC manufacturing industries using data for the period 1969 to 1980. Finally, Truong [1986] has estimated a model of substitution between capital, labour and energy model for NSW manufacturing using data for the period 1968/69 to 1982/83.

The present study, therefore, is the first known empirical research to make use of data at the level of the establishment. The availability of these data enables the estimation of models on data applicable to them and enables the construction of appropriate marginal price variables for gas and electricity. Moreover, the availability of data at the establishment level allows the use of a large number of observations. This is in direct contrast to the previous studies that use aggregate data in which data points are limited by relatively short time series and are plagued by changing variable definitions in official statistics over time.

2. Overview

2.1 Introduction

In this section the structure of the report is outlined, an aggregate view of the industrial demand for energy in the NSW manufacturing sector is provided, and the general research strategy is briefly discussed.

2.2 Structure of the report

The research embodied in this report involves the estimation of econometric models using a very large data base with the objective of obtaining estimates of demand functions for energy inputs in the NSW manufacturing sector. These estimates will then be used by others to help forecast future demands and to evaluate policy programs. The report accordingly focuses separately upon the main ingredients and outcomes of this research.

Section 3 below deals with the theoretical basis for, and specification of, the econometric models that are employed. Section 4 then examines the data base used in the light of the requirements of the econometric model. This is done in a general way, the details of data sources and construction of the variables being described in Appendix A. Two related models, denoted as models A and B, are considered in this study. Section 5 presents and discusses the elasticity estimates obtained from model A, while the results from model B constitute the subject of section 6. Section 7 then considers the question of how the results may be used for policy and forecasting purposes. Finally, section 8 provides some concluding comments.

Section 3 is concerned with the econometric model. It outlines the economic theory underlying the empirical model and discusses various issues related to its implementation. The approach taken is that, since the data points are for individual establishments, one should make as much use of the microeconomic theory of the firm as is feasible. Accordingly, it is assumed that establishments choose their energy and non-energy input quantities so as to minimize the cost of producing their chosen levels of output. On the basis of this assumption and the assumptions that firms are price-takers and that the technology is given at any time, the establishments' demands for each input depends upon the prices for all the inputs, the level of output, and the state of technology (which we index by time).

There are variations on this theme that have been used in the empirical literature. Some researchers treat energy as a single aggregate input. In this case the demand for energy (as an aggregate) depends upon the price index for energy, the prices of other inputs, output, and time. Others add to this an energy sub-model that determines the demand for each fuel (energy type) as a function of the prices of fuels and the aggregate energy demand, which is determined in the broader model. Some researchers deal only with the energy sub-model and focus upon inter-fuel substitution.

All such models, however, are based upon the theory of cost minimization. They typically employ one of the so-called "flexible" functional forms for the cost function to allow the factor demand functions actually estimated to be consistent with a wide range of technologies and to allow the data to determine the parameters with as few restrictions as possible.

In the present study a flexible function form - the translog - is used on a model that encompasses four energy types (coal, oil, gas and electricity) as well as labour and capital. No separability restrictions that are implicit in the sub-modelling approach are thus employed.

Section 3 also considers various issues related to the implementation of the model. One issue relates to the fact that many different fuel patterns are observed to be used in practice. Not all establishments use all fuels; indeed, in only 342 out of 64,952 observations are all four fuels actually used. This requires the estimation of the model over each of the empirically relevant fuel patterns of which there are nine. A second issue relates to the fact that gas and electricity are sold on declining block schedules rather than at given prices. This leads to the result that a cost minimizing firm will choose an input like gas such that the marginal product of gas is proportional to its marginal price not its average price and, as a consequence, it is the marginal price of gas that is the appropriate explanatory variable.

Section 4 provides a brief examination of the data. The implications of the points raised in the previous paragraph for the construction of the variables used in the empirical model are discussed.

Sections 5 and 6 provide most of the results. Section 5 is devoted to model A which requires most but not all of the parameters relating to the responsiveness of demands to prices to be the same for each industry subdivision. Model B in section 6 allows all parameters to be different for each subdivision. The aggregate elasticity estimates are obtained as weighted averages of elasticities for each fuel pattern. They therefore represent market elasticities and can therefore be interpreted as responses by the subdivision in question to changes in prices, outputs and time.

It is found that, as a general rule, gas and electricity (and to a lesser extent, oil) have elastic demands with respect to their own prices. Labour and capital tend to have inelastic demands. Coal's elasticity varies more and, because of the relatively few establishments using coal, it is somewhat less reliably estimated. The output and time effects are not well estimated on the whole.

Section 7 indicates how these results may be used by those interested in policy questions and forecasting. Here the emphasis is on the techniques and assumptions rather than the empirical implementation.

2.3 Aggregate view of the NSW manufacturing sector

In this subsection some aggregate data on the industrial demand for the various inputs considered in this study are presented and briefly discussed. The purpose is to provide a general overview of the structure of the NSW manufacturing sector especially with respect to its demand for various forms of energy.

Table 2.1 provides estimates of the quantities of the various inputs used in the twelve different ASIC subdivisions of the NSW manufacturing sector in 1984/85. Several points should be noted about the data provided in this and subsequent tables. First,

Table 2.1 Quantities of inputs and output in NSW manufacturing, 1984/85

Industry	COAL	OIL	GAS	ELEC	LABOUR	CAPITAL	OUTPUT
21	3750.017	1443.253	4850.347	3264.293	50.057	1841221.291	610908.900
23	768.815	154.939	865.556	572.005	8.802	234351.916	107863.233
24	0.000	33.865	111.075	224.343	21.599	270363.333	137654.193
25	332.082	455.540	394.594	774.105	23.634	522961.702	154156.705
26	0.000	87.633	3914.845	2861.494	37.227	1045087.319	366279.256
27	1302.174	483.043	16283.231	4265.277	24.500	1558850.036	364385.203
28	9970.432	509.824	12668.600	1834.271	12.509	525888.238	166173.116
29	3351.295	1572.355	19873.449	14938.484	38.672	1902276.221	565995.300
31	106.461	201.110	1485.744	982.042	35.912	741395.505	230655.106
32	24.123	243.031	742.316	858.091	31.994	583127.470	276706.408
33	202.897	174.135	2175.349	1366.233	53.701	1355565.356	499263.222
34	2378.769	172.959	762.420	1275.935	20.767	525784.958	208825.286
Total	22187.066	5531.689	64127.526	33216.572	359.374	11106873.344	3688865.928

Notes

(a) The quantities of coal, oil, gas and electricity are in thousands of gigojoules (GJ).

(b) Labour is measured in thousands of employees.

(c) Capital and output are measured as quantity indices. For output the measure may be interpreted as real value added in thousands of 1968/69 dollars.

Table 2.2 Quantities of inputs per $1000 of output in NSW manufacturing, 1984/85

Industry	COAL	OIL	GAS	ELEC	LABOUR	CAPITAL
21	1.627	.626	2.105	1.417	.022	798.982
23	2.206	.445	2.484	1.641	.025	672.468
24	0.000	.070	.229	.463	.045	557.746
25	.436	.598	.518	1.016	.031	686.094
26	0.000	.054	2.416	1.766	.023	645.019
27	.743	.276	9.291	2.434	.014	889.431
28	13.861	.709	17.612	2.550	.017	731.102
29	1.554	.729	9.216	6.927	.018	882.136
31	.091	.172	1.272	.841	.031	634.676
32	.023	.232	.708	.819	.031	556.324
33	.104	.089	1.116	.701	.028	695.528
34	3.152	.229	1.010	1.691	.028	696.654
Total	1.472	.367	4.256	2.204	.024	737.088

Notes

(a) The quantities of coal, oil, gas and electricity are in thousands of gigojoules (GJ).

(b) Labour is measured in thousands of employees.

(c) Capital and output are measured as quantity indices. For output the measure may be interpreted as real value added in thousands of 1968/69 dollars.

the totals are for establishments that were used in the study and therefore excludes those that were discarded because of lack of information on some important variables. Consequently totals may not agree with those provided in ABS publications. Second, the definitions of the 2-digit ASIC subdivisions are provided in Table 4.2 below. Third, the figures for gas, electricity, output and capital are based partly upon extraneous data since the CME data base is not sufficiently comprehensive to obtain these figures using the CME data base alone. Details on how the variables were constructed are provided in section 4 and Appendix A.

Table 2.1 shows that the major form of energy used in gigojoules (GJ) in NSW manufacturing is gas with 64,127,526 GJ being used in 1984/85, followed by electricity with 33,216,572 GJ. In fact, gas is the dominant form of energy in 8 out of the 12 industry subdivisions.

The largest user of coal is ASIC subdivision 28 (non-metallic mineral products), while ASIC subdivision 29 (basic metal products) is the biggest user of oil, gas and electricity.

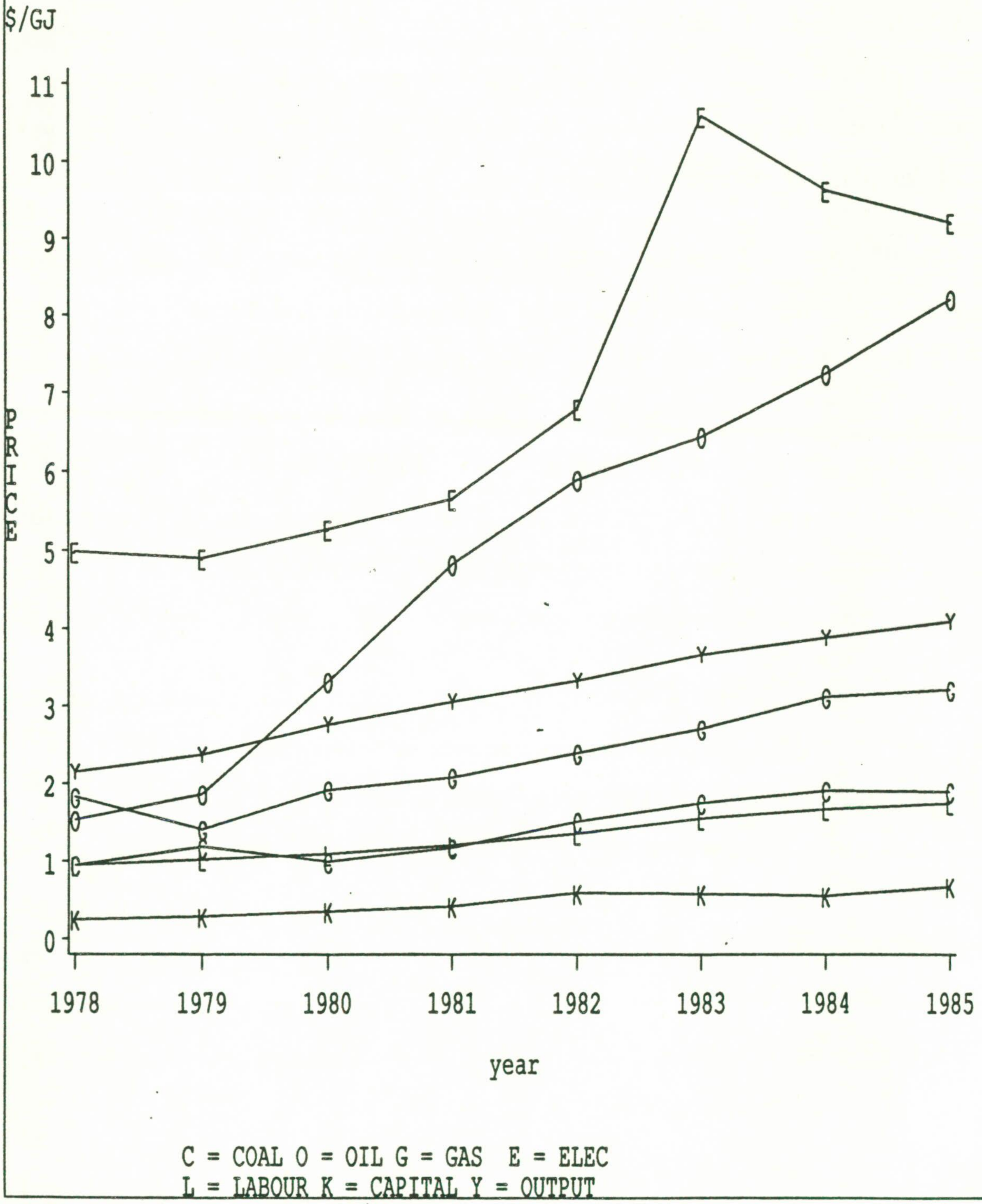
Another measure of the importance of the various inputs is in terms of the quantities used per $1000 of output (value added) in each industry subdivision. These figures are presented in Table 2.2. In the manufacturing sector as a whole over twice as much gas (4.256) as electricity (2.204) is used per $1000 of output. Much less coal (1.472) and very little oil (0.367) is used. Subdivision 28 is clearly the most intensive user of coal with 13.861 GJ per dollar of value added, and of gas with 17.612 GJ per dollar of value added. Subdivision 29 has the greatest intensity of use of electricity with 6.927 GJ per dollar of value added, while it and subdivision 27 have high intensities of use of gas.

The most labour intensive industry subdivision is 24 (clothing and footware) while the least labour intensive subdivision is 27 (chemical, petroleum and coal products). Capital intensity is highest in subdivisions 27 and 29 and lowest in 24 and 32 (transport equipment).

Trends over time in quantities and prices of the various inputs and outputs are depicted graphically in Figures 2.1, 2.2 and 2.3. Figure 2.1 shows how quantities of the inputs and output (real value added) in the NSW manufacturing sector as a whole have changed over the period 1977/78 to 1984/85. Figure 1.2 removes gas from Figure 1.1 and enlarges it to show more detail for the remaining input and output variables. All quantity variables have been indexed to be unity in 1977/78.

Figure 2.1 shows a dramatic increase in the quantity of gas used by the NSW manufacturing sector, increasing over 4-fold in the 8-year period. Over this same period the quantity of oil used has fallen substantially to now be one-tenth of what it was in 1978. The demand for electricity has grown by about 50 percent over this period, but the growth has not been uniform. The use of coal has declined by about 20 percent. The quantities of output (value added), labour and capital have remained fairly steady over this period.

Figure 2.3 N.S.W. manufacturing: price indices, 1977/78 – 1984/85



Note: The price of electricity has been divided by 2 to facilitate the appearance of the graph.

Figure 2.1 N.S.W. manufacturing: quantity indices, 1977/78 – 1984/85

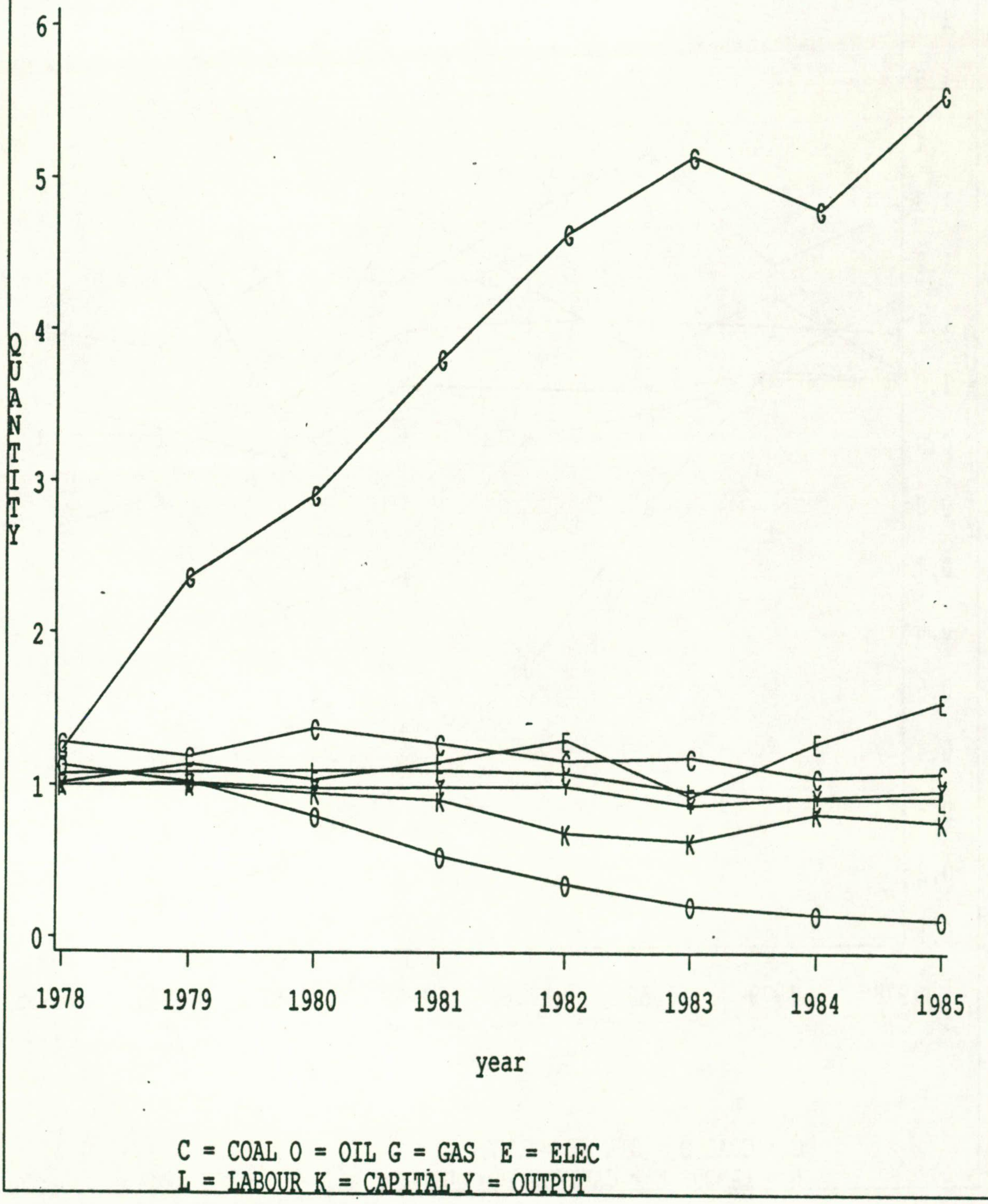
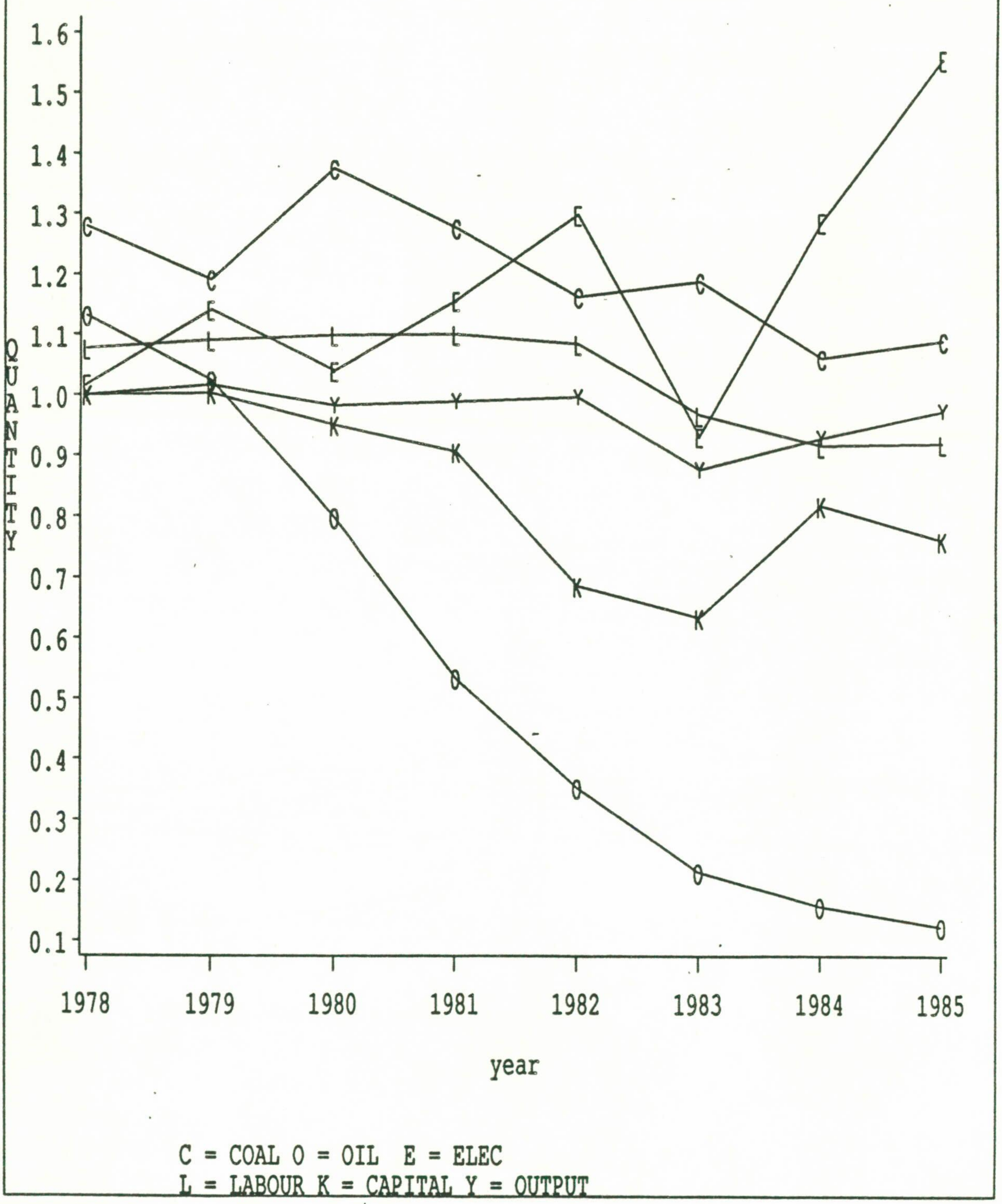


Figure 2.2 N.S.W. manufacturing: quantity indices, 1977/78 – 1984/85



Trends in average prices for the NSW manufacturing sector as a whole are depicted in Figure 2.3. The prices are expressed in dollars per GJ. The figure shows the dramatic increase in the price of oil over the period, rising from about $1.53 in 1977/78 to $8.20 in 1984/85. On the whole the prices of the other inputs and output have risen steadily since 1977/78. Note, however, the fairly rapid rise in the price of electricity in 1982/83 corresponding to a fall in the demand in that same period.

The percentage increases in the prices of the inputs and output over the 8-year period was: coal - 99%, oil - 436%, gas - 76%, electricity - 85%, labour - 84%, capital - 171%, and output - 90%. Relative to electricity, oil has become much more expensive, capital more expensive, and gas somewhat less expensive. These changes in relative prices are certainly factors that have influenced the changes in quantities as described in Figures 2.1 and 2.2.

Electricity is the most expensive form of energy with an average price of $18.40 per GJ in 1984/85, followed by oil at $8.20 per GJ, then gas at $3.21 per GJ, and the cheapest is coal at $1.89 per GJ.

While the data presented in these figures and tables are useful in providing an overall view of the structure of the NSW manufacturing industry, such aggregate data subsume an enormous amount of valuable information. This information consists of data such as that presented above, but for each individual establishment not the sector as a whole. It is the analysis of that detailed data set to which attention is now turned.

2.4 **Research strategy**

Underlying all empirical investigations is a maintained hypothesis or set of assumptions, which determine the nature of the empirical study. The empirical work in this study is based upon the economic theory of cost minimization behaviour on the part of establishments. In this section the econometric model is briefly outlined within the context of such behaviour. In section 3 below a full development of the econometric model is provided.

General

The assumption of cost minimization behaviour is a common one in theoretical and applied analysis of producer behaviour. In the present context the assumption is that each establishment chooses quantities of each of the inputs to the production process, namely the quantities of coal, oil, gas, electricity, labour and capital, to minimize the cost of producing the output of the establishment. The establishment takes as given the prices of each of the inputs and the level of output is taken as given, being determined within the broader context of profit maximization. Also given is the state of technology characterized by the production function, which indicates how much output each feasible combination of inputs can produce.

Given that the establishment is to produce a specific level of output, it has to decide how much of each of the inputs to use to achieve that level of production. Since there may be many different combinations of input quantities that will produce the specified output, some criterion for the choice is needed. The criterion assumed is one of the cost of production. Each feasible combination of inputs will, at the given prices for inputs, determine a cost of production. The establishment is assumed to choose that combination of input quantities that yields the lowest possible cost of producing the specified level of output.

The solution to the cost minimization problem determines the demands by the establishment for each of the inputs as functions of the prices of all the inputs and the level of output. It is the estimation of these demand functions and their analysis that is the focus of the study. Of particular interest is the responsiveness of the demands for coal, oil, gas and electricity to their prices and to output changes. They may also be used to obtain forecasts of future demands, given a scenario of how the input prices and outputs will change in the future.

Let y be the level of output of the establishment, $p=(p_1,\ldots,p_n)$ be the vector of prices of the n inputs, and $x=(x_1,\ldots,x_n)$ be the vector of quantities of the n inputs used, and $s=(s_1,\ldots,s_n)$ be the vector of shares of each of the inputs in the cost of production. Then the demand functions for the inputs arising from the solution to the cost minimization problem of the establishment may be expressed mathematically as

$$(2.1)\quad x_i = \phi_i(p_1,\ldots,p_n,y) \qquad i=1,\ldots,n.$$

This says that the quantity demanded of input i (x_i) depends in a particular way (defined by the function ϕ_i) upon the prices of all of the inputs ($p_i,\ldots,p_n$) and the level of output (y). These relationships (demand functions) are the focus of the study since they relate an establishment's use of energy inputs to various explanatory variables (prices and output).

By observing the input quantities used by establishments in the NSW manufacturing sector over the 8-year period 1977/78-1984/85 together with the input prices and output quantities the parameters of a specific functional form for ϕ_i may be estimated using econometric techniques. This task constitutes the major part of the project.

Once the demand functions (2.1) have been estimated, they may be used to predict the demands for the inputs (which include various forms of energy) at some future date if it is assumed that the demand relationships continue to hold and if we have forecasts of the input prices and output.

The above discussion may be summarized as follows. Establishments are assumed to choose inputs of various forms of energy (such as coal, oil, gas and electricity) as well as other inputs (labour and capital) to minimize the cost of producing the output. This determines the establishment's demands for various forms of energy and the other inputs as functions of the prices of all the inputs and output. These demand functions are estimated using econometric techniques on the large NSW Census of Manufacturing data base. They may then be used to provide forecasts of future energy demands by manufacturing establishments.

Specifics

The estimation procedure actually used is a little more complex than indicated above, and is now briefly outlined.

The main part of the estimation procedure is the estimation of the input cost share equations. Given a translog cost function (a particular functional form) the input cost share equations may be written as

$$(2.2)\quad s_{ih} = a_i + \Sigma_{j=1}^{n} b_{ij} \ln p_{jh} + c_i \ln y_h + \Sigma_{k=1}^{L} d_{ik} D_{kh} + e_i t_h + u_{ih}$$

where subscript h denotes the observation on a particular establishment in a particular year, C_h is its observed cost of production, s_{ih} is the observed share of factor i in the cost of production of h, p_{jh} is the price of input j paid by h, y_h is the level of output of h, D_{kh} is a dummy variable equal to unity if h is in industry k and zero otherwise, t_h is the year in which h is observed, u_{ih} is the random disturbance of factor i for h.

This states that the share of input i in the cost of production of establishment h is a linear function of the logs of the prices of the inputs, the log of output, the industry dummy variables, time, and the stochastic disturbance. The importance of prices and output have been previously explained. The time variable is introduced to allow for changes in the technology and other factors (other than prices and output) that affect the demand for inputs and change over time. The industry dummy variables have the effect of allowing a different intercept for each industry. For example, if the establishment is in industry 2 then the intercept is (a_i+d_{i2}). Thus, by allowing the intercepts to be different, the d_{ik} parameters attached to the industry dummy variables allow for differences in the technology among industries. This model is referred to as **Model A.**

These differences are limited to the intercepts. In **Model B** all of the parameters in the share equations are allowed to be different from one industry to another, thus allowing complete differences in technologies.

In the translog model the share equations, while very convenient to estimate in view of their linearity, do not contain enough information to obtain the demand functions such as (2.1). The demand by establishment h for input i is given by

$$(2.3)\quad x_{ih} = s_{ih}C_h/p_{ih} \qquad i=1,..,n$$

which is simply a re-arrangement of the definition of the cost share of input i as $s_{ih}=p_{ih}x_{ih}/C_h$, where C_h is the total cost of production of establishment h. For the translog functional form chosen it turns out that C_h factors into two parts as $C_h=G_h.H_h$ and so the demand for input i by establishment h may be written as

$$(2.4)\quad x_{ih} = F_{ih}.H_h \qquad i=1,...,n$$

where F_{ih} depends upon all of the explanatory variables and the parameters of the share equations (2.2) and so may be calculated once the share equations are known, and H_h is a function of the explanatory variables other than prices and depends on a different set of parameters.

The parameters of function H_h are assumed to be different in each industry and are estimated by a procedure described in detail in section 3 below. Once the share equations have been estimated and the parameters of the function H have been estimated, a complete explanation of the input quantities will have been obtained.

Some other complications, also explained in detail in section 3, arise in the empirical work. First, the share equations are estimated separately for each fuel pattern observed, since there are good grounds for believing that the technologies will be different under different fuel pattern usage. Secondly, the prices that enter the share and demand functions are required to be marginal prices not average prices. This follows from the assumption that establishments minimize their costs.

Elasticities

The responses of establishment's demands for inputs to changes in the explanatory variables are described by elasticities. Thus, in the empirical section we report price elasticities, output elasticities and rates of time change. These are defined, in general terms, as follows (where Δ denotes "change in").

Own-price elasticity of demand for input i

(2.5) $\partial \ln x_i / \partial \ln p_i = (\Delta x_i / x_i) / (\Delta p_i / p_i)$ = percentage change in x_i due to a 1 percent increase in p_i

Cross-price elasticity of demand for input i

(2.6) $\partial \ln x_i / \partial \ln p_j = (\Delta x_i / x_i / (\Delta p_j / p_j)$ = percentage change in x_i due to a 1 per cent increase in p_j $(j \neq i)$

Output elasticity of demand for input i

(2.7) $\partial \ln x_i / \partial \ln y = (\Delta x_i / x_i) / (\Delta y / y)$ = percentage change in x_i due to a 1 percent increase in y

Rate of time change

(2.8) $\partial \ln x_i / \partial t = (\Delta x_i / x_i)/\Delta t$ = percentage change in x_i due to a unit increase in t (passage of 1 year)

Each of these elasticities indicates the change in x_i due to a change in one of the explanatory variables, keeping all other explanatory variables fixed. They are convenient measures of the responsiveness of input demands to changes in the explanatory variables

3. The econometric model

3.1 Introduction

The general research strategy and an outline of the econometric model used in the empirical work were provided in section 2.3 above. The purpose of this section is to provide further details for those whose primary interest is "behind the scenes", that is, in how the estimation was done and why. Those whose primary interest is in the empirical results themselves can proceed without any real loss of continuity to section 4.

In section 3.1 below the theory of the demand for inputs as a result of cost minimizing behaviour by establishments is outlined and the actual functional forms chosen for the empirical work are presented and discussed. In section 3.2 the adjustments to deal with variations in the technology over ASIC subdivisions and time are specified. Sections 3.4 and 3.5 deal with some special complications relating to "corner solutions" and the need for use of "marginal prices" in the empirical work. Finally, section 3.5 completes the model specification, looks at demand functions for inputs at the ASIC subdivision rather than the establishment level, and indicates how the elasticities presented in the empirical results section are calculated.

3.2 Cost minimization and cost share equations

It is assumed that each establishment faces given prices $p_1,\ldots,p_n$ for each of the n inputs it uses to produce its output. Let $(x_1,\ldots x_n)$ be the quantities of the n inputs used, y be the level of output, and the production function, indicating the amount of output that is technologically feasible for given quantities of inputs, be $f(x_1,\ldots,x_n)$. Then the establishment's cost minimization problem is to choose $x_1,\ldots,x_n$ to produce output y at the smallest possible cost $p_1x_1+\ldots+p_nx_n$. For a given output y, prices of inputs $(p_1,\ldots,p_n)$, and production function (technology) $f(x_1,\ldots,x_n)$ there is a solution for the input quantities $(x_1,\ldots,x_n)$ and so the total cost $p_1x_1+\ldots+p_nx_n$. If the exogenous variables y and $(p_1,\ldots,p_n)$ are varied, the solution for $(x_1,\ldots,x_n)$ and $p_1x_1+\ldots+p_nx_n$ vary in response. This yields the cost function C(p,y) defined as

$$(3.1)\quad C(p,y) = \min p_1x_1+\ldots + p_nx_n \text{ subject to } f(x_1,\ldots x_n)\geq y, \text{ and } (x_1,\ldots,x_n)\geq 0.$$

The factor demand functions $X_i(p,y)$ may be obtained from the cost function by differentiation with respect to the prices as

$$(3.2)\quad X_i(p,y) = \partial C(p,y)/\partial p_i \qquad i=1,\ldots,n$$

a result often referred to as Shephard's Lemma. If we define the share of factor i in the total cost of production as

$$(3.3)\quad s_i = p_ix_i/\Sigma_{j=1}^{n}p_jx_j \qquad i=1,\ldots,n$$

then it turns out that

$$(3.4)\quad s_i = \partial \ln C(p,y)/\partial \ln p_i \equiv S_i(p,y) \qquad i=1,\ldots,n$$

where ln denotes the natural log and where (3.2) has been used.

The strategy used to obtain an empirically estimable econometric model is to choose a functional form for the cost function C(p,y) and to obtain equations explaining the shares of the factors in total cost by logarithmic differentiation as in

(3.4). In the empirical work below a <u>translog</u> functional form for C(p,y) is chosen. This function is defined by

$$(3.5)\ \ln C(p,y) = \ln H + \Sigma_{i=1}^{n} a_i \ln p_i + (1/2)\Sigma_{i=1}^{n}\Sigma_{j=1}^{n} b_{ij} \ln p_i \ln p_j + (\Sigma_{i=1}^{n} c_i \ln p_i) \ln y,$$

where lnH does not depend upon input prices and will be specified further below, and where the parameters obey certain restrictions to ensure that the cost function is homogeneous of degree one in input prices and is uniquely identified in terms of the parameters. These restrictions are

$$(3.6)\ \Sigma_{i=1}^{n} a_i = 1\ ;\ \Sigma_{i=1}^{n} b_{ij} = 0 \qquad j=1,..,n;$$

$$\Sigma_{i=1}^{n} c_i = 0;\ \text{(homogeneity)}$$

$$b_{ij} = b_{ji} \qquad i,j = 1,..,n\ (i \neq j) \quad \text{(symmetry)}$$

The translog cost function is commonly used in empirical work of the sort being undertaken in this report. It belongs to the class of "flexible functional forms", which have enough parameters to enable the function to approximate an arbitrary function up to the second order. In the current context this means that any valid matrix of price and output elasticities can be obtained from this functional form. It is therefore very flexible and, within certain general limits, allows the data considerable leeway to determine the values of these elasticities. This is in contrast to functions such as the CES (constant elasticity of substitution) function that considerably restrict the values that substitution elasticities can take.

The parameter restrictions specified in (3.6) provide some basic restrictions required from economic theory. The homogeneity restriction ensures that a doubling of all input prices would not alter input choices for a given output level but would simply double the cost of production.

Being quadratic in the logs of prices, the translog cost function yields linear share equations of the form

$$(3.7)\quad S_i(p,y) = a_i + \Sigma_{j=1}^{n} b_{ij} \ln p_j + c_i \ln y \qquad i=1,\ldots,n$$

These equations show how the input shares depend upon the explanatory variables, namely the input prices and the level of output.

These equations are particularly convenient for econometric estimation as they are linear in parameters and linear in the logarithms of variables. The demand functions by contrast are highly nonlinear and are therefore much less convenient (and more expensive) to estimate. Accordingly, we choose the share equations (3.7) as the basis for the econometric work. The left-hand side is replaced by the observed share for each establishment and a random disturbance is added to the right-hand side to represent errors of optimization by establishments. Thus, with establishment data on prices, output and factor shares the equation system (3.7) is estimated as a multivariate equation system.

3.3 Technology variations over time and ASIC subdivisions

Of course, not all establishments will have the same technology. To take account of differences in technology it is assumed that the cost function, and, hence, the factor demand and share equations, depend upon two additional sets of variables. The first is the variable t which indicates the year of observation. With the passage of time comes technological change and, in the absence of a suitable economic explanation for it, the traditional procedure of assuming that the state of technology is a simple function of time is followed. Second, it is assumed that there are differences in technology between 2-digit ASIC subdivisions within the manufacturing sector. In one set of models estimated the assumption is that the technologies (hence cost and share equations) are quite unrelated between subdivisions. In another set of models, the parameters $a_1,\ldots,a_n$ are assumed to be different between sectors but that all other parameters are common to all sectors.

With these additional features, and introducing random disturbances to represent deviations of actual from optimal behaviour, it is assumed that

$$(3.8)\quad \ln C_h = \ln H + \Sigma_{i=1}^{n} a_i \ln p_{ih} + (1/2)\,\Sigma_{i=1}^{n}\Sigma_{j=1}^{n} b_{ij} \ln p_{ih} \ln p_{jh} + (\Sigma_{i=1}^{n} c_i \ln p_{ih}) \ln y_h + \Sigma_{i=1}^{n} \ln p_i\, \Sigma_{k=1}^{L} d_{ik} D_{kh} + (\Sigma_{i=1}^{n} e_i \ln p_{ih}) t_h + \Sigma_{i=1}^{n} u_{ih} \ln p_{ih}$$

whence

$$(3.9)\quad s_{ih} = a_i + \Sigma_{j=1}^{n} b_{ij} \ln p_{jh} + c_i \ln y_h + \Sigma_{k=1}^{L} d_{ik} D_{kh} + e_i t_h + u_{ih} \qquad i=1,\ldots,n$$

where subscript h denotes the observation on a particular establishment in a particular year, C_h is its observed cost of production, s_{ih} is the observed share of factor i in the cost of production of h, p_{jh} is the price of input j paid by h, y_h is the level of output of h, D_{kh} is a dummy variable equal to unity if h is in industry k and zero otherwise, t_h is the year in which h is observed, u_{ih} is the random disturbance of factor i for h. This is the model whereby limited differences between industries (restricted to the intercepts) are permitted. It will be referred to subsequently as **Model A.**

The alternative model, which will be referred to as **Model B**, occurs when <u>all</u> parameters are industry dependent. Thus the share equations become

$$(3.10) \quad s_{ih} = a_{ik} + \Sigma_{j=1}^{n} b_{ijk} \ln p_{ih} + c_{ik} \ln y_h + e_{ik} t_h + u_{ih}$$

where the subscript k denotes industry k and h is restricted to that industry.

Both models A and B express input cost shares as functions of prices, output and time, but differ in the extent to which they allow the parameters to vary from one industry to another. Both include an additive disturbance term u_{ih} to account for errors in cost minimization by establishments and the effects of all other variables not included in the model but which may have an effect upon input cost shares.

It is assumed that the vector of disturbances $u_h=(u_{1h},...,u_{nh})$ is stochastic and has a multivariate normal distribution with zero mean and a constant, positive semi-definite covariance matrix and that the u_h (h=1,2,...) are stochastically independent. The parameters of the share equations are estimated by the method of maximum likelihood.

3.4 **Corner solutions**

There is an important point to consider before proceeding to the empirical implementation of the model, and this concerns the possibility of "corner solutions" to the cost minimization problem in which one or more of the inputs has a zero value. Such solutions create special difficulties for the empirical work.

Solutions with one or more factors not being used can occur as a result of two alternative situations. First, the technology may not allow or require a particular input. Second, even if all factors are relevant the prices of the factors may be such, relative to the technology, that it is not economical to use all factors. For example, it may be uneconomical to use coal or oil in a particular production process if these are priced highly relative to their contribution to output; gas and electricity may be cheaper sources of energy for that process.

It turns out that most observations in the data set do not have all four fuels being used. There are 16 (equal to 2^4) possible patterns of fuel consumption, of which 9 are empirically relevant (have a sufficient number of observations for estimation). The case of all four fuels being used is one of these but it is one of the minor (in terms of number of observations) of the empirically relevant patterns.

Accordingly, consideration must be given to this variety of fuel patterns observed. Unfortunately, it is not defensible to estimate the models given above using all observations, since such a procedure yields biased and inconsistent estimates due to "sample selectivity". The procedure adopted here is to estimate the models separately for every observed pattern of fuel use, on the grounds that the technology will be different for each pattern. For example, if factor 1 is not utilized the production function for the establishment, conditional upon $x_1=0$, is $f(0,x_2,\ldots,x_n)$, while the production function conditional on factor 2 not being used is $f(x_1,0,x_3,\ldots,x_n)$. While derived from the same function f, these are different conditional functions. The techniques needed to estimate the common technology f using all observations and taking into account the cost minimization reasons for the particular pattern observed for each establishment are very complex and are too expensive to follow in this project. Accordingly, we treat the conditional production functions as separate functions and so the share equations are estimated for each of the empirically relevant fuel patterns observed.

3.5 Price schedules for electricity and gas

The Problem

The analysis of the demands for fuels is complicated by the practice employed by suppliers of charging a price for fuels such as gas and electricity that depends upon the quantity used by the establishment. Establishments do not, therefore, face a single market price for these energy types. Instead, they face a complete price schedule that specifies what the price will be at each level of consumption. A complete and comprehensive treatment of this issue is beyond the scope of this project, since it would involve quite complicated estimation procedures. In this section the nature of the problem created by the existence of price schedules is outlined, and an incomplete but acceptable accommodation of the problem as used in the empirical work is provided.

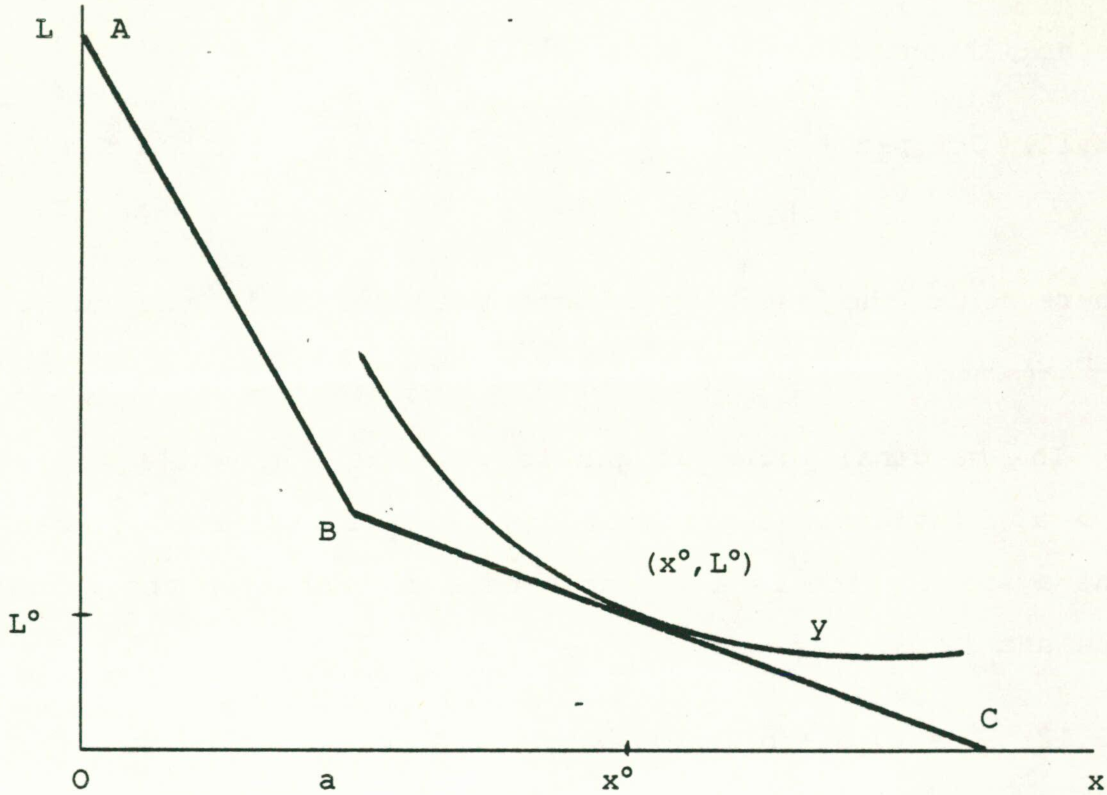


Figure 3.1 **Cost minimization with a declining block price schedule**

Illustration

To illustrate the main issues consider an establishment that uses two inputs, say gas and labour, to produce its output (the inclusion of additional inputs is straightforward). Suppose that the price of gas for the first a units is p_1, and the cost of each additional unit purchased beyond a is p_2. For labour the given wage rate is w. If, as is commonly the case, gas has a declining block pricing schedule then $p_2 < p_1$. The cost to the establishment is

$$(3.11) \quad C = \begin{cases} p_1 x + wL & \text{if } 0 \leq x \leq a \\ p_1 a + p_2(x-a) + wL & \text{if } a < x, \end{cases}$$

where x is the quantity of gas used and L is the quantity of labour used.

The marginal price of gas is p_1 if $x \leq a$, while it is p_2 if $x > a$. The average price of gas is p_1 if $x \leq a$, but when $x > a$ the average price is a variable that depends upon the purchase of gas and is

$$(3.12) \quad P = (p_1 a + p_2(x-a))/x$$

The solution to the cost minimization problem is illustrated in Figure 1. If y is the output to be produced, the feasible input combinations are on the drawn isoquant. The lowest cost occurs at (x^o, L^o) and the minimal isocost line ABC is drawn also.

What is crucial for an optimal solution is for the isoquant and the isocost line to be tangential as they are at (x^o, L^o). The slope of the isocost line along segment AB is $-w/p_1$, while along segment BC, where $x > a$, the slope is $-w/p_2$. These slopes differ because $p_1 \neq p_2$ and BC is flatter than AB because $p_2 < p_1$.

The solution (x^o, L^o) is characterized by equality of the slopes of the isoquant and the isocost line (the first-order condition for cost minimization), and the latter is determined by the marginal price for each segment. It is, therefore, the marginal price that is relevant to cost minimization decisions by establishments, not the average price.

Solution

A complete analysis of the problem would recognize that the whole price schedule is relevant, and that other complications such as multiple solutions can arise. However, the approach taken here is to assume that observed input points are "close enough" to the cost minimizing input points so that the observed marginal price (marginal price corresponding to the observed input of the factor of production) is the relevant one. In Figure 1 we assume that the observed and cost minimizing input choices are both on segment BC, so p_2 is the relevant marginal price.

The procedure adopted has been used extensively in the analysis of labour supply under a progressive tax structure, where the same issues arise. See, for example, Wales and Woodland [1979].

In the present context, we use the observed quantity of, say, gas to obtain from the price schedule the observed marginal price of gas. This is the extra cost of an extra unit of gas purchased by the establishment. This marginal price is used as the price of gas in the calculation of shares and as an explanatory variable in the share equations.

3.6 The full cost function and aggregation over fuel patterns

In this section the fuel cost function is completely specified by specifying the nature of lnH, the demand functions are aggregated over the fuel patterns and the elasticities computed and presented in the empirical results are defined.

The full cost function

The cost function becomes fully specified by specifying the nature of lnH which appears in (3.5), but which is not relevant to the share equations. We specify that

$$(3.13) \quad \ln H = \Sigma_{k=1}^{L} g_k D_k + f.\ln y + h.t$$

where y is the level of output, D_k is a dummy variable equal to unity if the establishment is in industry k and zero otherwise, and t is time in years. The parameters are f, $g_1, \ldots, g_L$, and h.

In section 3.3 it was argued that it is necessary to take account of different fuel patterns that can, and do, arise. Accordingly, the share equations (3.10) were estimated separately for each fuel pattern. This means that the "price parameters" (a, b, c, e) appearing in (3.10) are different for each fuel pattern.

While the "non-price parameters" (f, g, h) could be similarly differentiated by fuel pattern, this would have required additional equations to be estimated for each fuel pattern. In addition, it would be more difficult to use the results for the purpose of calculating elasticities and of making forecasts.

This is because the researcher would need to know how the output, for example, of the industry (for which a forecast, for example, is required) is distributed over the different fuel patterns. This information is unlikely to be readily available in the absence of a model explaining the choice of fuel pattern. Thus, it was decided that an alternative approach was necessary to facilitate easier use of the empirical results.

The approach taken was to assume that the price parameters do vary by fuel pattern, thus accommodating the argument in section (3.3), but that the non-price parameters appearing in (3.13) do not vary by fuel pattern. These parameters are, however, likely to vary over ASIC industry subdivisions.

Aggregation

For a particular establishment observation h we have that the share of input i denoted as s_{ih} is given by (3.10). The quantity demanded of input i is thus

(3.14) $x_{ih} = s_{ih}C_h/p_{ih} = (s_{ih}G_h/p_{ih})\ H_h = F_{ih}\ H_h$

where

(3.15) $C_h \equiv G_L \cdot H_h$ and $F_{ih} \equiv S_{ih}G_L/p_{ih}$

and lnG is price component of the righthand side of (3.5).

Summing the input quantities (3.14) over h in a particular industry we obtain the aggregate demand for input i as

(3.16) $X_i \equiv \Sigma_h\ x_{ih} = \Sigma_h\ F_{ih} \cdot H_h$ $\qquad i=1,\ldots n$

Since access to share predictions for each establishment (needed to calculate F_{ih}) was not permissible, (3.13) was approximated by

$$(3.17)\quad X_i = \Sigma_{j=1}^{9} F_i^j \,.\, H^j \,.\, \alpha_j \qquad i=1,\ldots,n$$

where superscript j denotes fuel pattern j. Here, F_i^j is the F_i function evaluated at the average values (over all establishment observations in each fuel pattern j) of each of the exogenous variables (input prices, output, industry dummies and time). Also, α_j is the proportion of establishments in the industry in question that exhibit fuel pattern j. Finally, H^j is the function H, defined by (3.13), evaluated at the same values for the exogenous variables.

There are n equations in (3.17) and they may be evaluated for each time series observation $t=1,\ldots,T\equiv 8$ for each industry subdivision. Adding stochastic disturbances to the righthand sides of (3.17) we obtain a set of n nonlinear multivariate equations containing unknown parameters (f, g, h). These parameters were estimated by applying standard nonlinear estimation procedures to the n equations in (3.17). Separate estimations were undertaken for each industry subdivision.

In summary, the "price parameters" (a, b, c, e) are estimated using establishment level observations for each fuel pattern. These estimates are then used to create the F_i variables and the "non-price" parameters (f, g, h) are obtained by estimating the set of nonlinear aggregate demand equations (3.17).

Aggregate elasticities

For each industry we have, as a result of the estimations, an estimate of the demand function for each input i in each fuel pattern j. These demand functions may be expressed as

$$(3.18)\quad x_{ij} = \phi_{ij}(p,y,t)$$

where x_{ij} is the quantity demanded of input i by the average firm in pattern j, ϕ_{ij} is the demand function, p is the price vector for the inputs, y is the average level of production, and t is time.

The aggregate demand function for input i is given by

$$(3.19)\quad X_i \equiv \Sigma_{j=1}^{9} x_{ij} = \Sigma_{j=1}^{9} \phi_{ij}(p,y,t)$$

and the effect of some exogenous variable, say θ, upon aggregate demand may be expressed as

$$(3.20)\quad \partial \ln X_i/\partial\theta \equiv \Sigma_{j=1}^{9} w_{ij}(\partial \ln x_{ij}/\partial\theta)$$

where $w_{ij} \equiv x_{ij}/X_i$. Thus the percentage change in X_i as a result of a unit change in θ is a weighted average of the percentage changes in the pattern specific input demands x_{ij}, the weights being the relative importance of pattern j in the total demand.

To make (3.20), which is a general relationship, more specific we can choose θ to be a variety of variables. If θ is taken to be $\ln p_i$ then the lefthand side of (3.20) is the own-price elasticity of demand for factor i; if θ is taken to be lny then it is the elasticity of demand for factor i with respect to output; and if θ is taken to be the time variable t then it is the percentage rate of change per unit of time of the demand for factor i.

The precise formulae corresponding to the translog functional form are not presented here but may be obtained using the definition of the cost function in (3.5) and (3.13), the input cost share functions given by (3.7) and the relationship defining the demand for input i in terms of the shares and cost, namely $x_i=s_iC/p_i$.

4. Data description

4.1 Introduction

The primary data set for this study is the ABS Census of Manufacturing Establishments (CME) for NSW and covering the 8 year period 1977/78 to 1984/85. A general description of the survey and definitions of variables is provided, along with tables of various summary statistics, in the annual publications of the ABS, specifically catalog numbers 8201.1, 8203.1 and 8204.1. In this section the data set is briefly discussed. Further detail is provided in Appendix A.

The CME contains a wide range of data relating to the operations of all manufacturing establishments in NSW. The ABS provided access to these data at the establishment level on a confidential basis. The operating rule was that the ABS would perform the data manipulations and statistical computations and would provide to this consultant only those outputs that preserved confidentiality regarding an individual establishment's data.

4.2 Numbers of establishments

The data set consists of approximately 80,000 observations on establishments and therefore contains a very large amount of information. Table 4.1 provides a breakdown of observations by ASIC industry 2-digit subdivision and year. The industry subdivisions are briefly described in Table 4.2.

The data coverage is clearly very comprehensive, with approximately 10,000 manufacturing establishments being observed each year. Table 4.1 also shows that the dominant industries in terms of the numbers of establishments are subdivisions 25 (wood, etc), 31 (fabricated metal products) and 33 (other machinery and equipment). The smallest numbers of establishments occur in subdivisions 23 (textiles) and 29 (basic metal products). However, it should be emphasised that there are large variations in the sizes of establishments so that Table 4.1 does not reflect the importance of industries in the demand for energy. As Table 2.1 indicates, subdivision 29 is clearly the dominant user of oil, gas and electricity though it has the least number of establishments.

One aspect of the data set that could not be exploited due to limited resources is its panel nature. Many establishments are observed each year and these observations may be identified as belonging to particular establishments. This aspect of the data can be powerfully exploited in statistical and econometric research, and this should be done. However, due to the closure of establishments, mergers, and so forth many establishments cannot be tracked through time. Accordingly, to economize on resources and to maintain as large a sample as possible, tracking of establishments through time was not undertaken.

4.3 Construction of variables

Each observation comprises information regarding the inputs and outputs of the establishment. However, since this information is not complete for the purpose of the present study, some additional information had to be obtained from other sources.

The econometric modelling of the production process requires data on various inputs and outputs of establishments, identified by their industrial classification for each year of observation.

Table 4.1 Numbers of establishments in CME (by subdivision and year)

Subdivision	Year								
	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	Total
21	991	988	1031	1031	1039	1038	1041	1004	8163
23	228	227	232	223	214	201	214	214	1753
24	868	785	793	762	771	789	756	808	6332
25	1257	1327	1396	1422	1488	1479	1421	1417	11207
26	1126	1140	1188	1236	1308	1302	1304	1304	9908
27	413	411	421	428	440	433	421	406	3373
28	564	574	583	594	611	600	588	579	4693
29	211	208	220	217	221	211	209	200	1697
31	1513	1570	1633	1703	1785	1765	1715	1691	13375
32	391	406	453	460	455	432	417	428	3442
33	1528	1598	1589	1625	1668	1642	1607	1582	12839
34	820	820	845	852	880	879	860	860	6816
Total	9910	10054	10384	10553	10880	10771	10553	10493	83598

Table 4.2 Definitions of inputs, industry subdivisions and fuel patterns

Inputs

Input No.	Name
1	coal
2	oil
3	gas
4	electricity
5	labour
6	capital

Industry subdivisions

No.	ASIC No.	Name
1	21	Food, beverages, and tobacco
2	23	Textiles
3	24	Clothing and footware
4	25	Wood, wood products, and furniture
5	26	Paper, paper products, printing, and publishing
6	27	Chemical, petroleum, and coal products
7	28	Non-metallic mineral products
8	29	Basic metal products
9	31	Fabricated metal products
10	32	Transport equipment
11	33	Other machinery and equipment
12	34	Miscellaneous manufacturing

Fuel patterns

No.	Included fuels			
1	coal,	oil,	gas,	electricity
2		oil,	gas,	electricity
3	coal,		gas,	electricity
4	coal,	oil,		electricity
5			gas,	electricity
6		oil,		electricity
7	coal,			electricity
8				electricity
9		oil		

The inputs defined for the econometric model outlined in the previous section are: coal, oil, gas, electricity, labour and capital. The industry subdivisions that define the dummy variables D_k are the ASIC 2-digit subdivisions described briefly in Table 4.2: 21, 23-29, and 31-34.

For each input i the data for each establishment observation consist of a price p_i, a quantity x_i and a value v_i. The four fuel inputs (coal, oil, gas and electricity) have quantities measured in gigajoules with prices measured in dollars per gigajoule.

For coal and oil the Census of Manufacturing Establishments (CME) provides data on x_i and v_i, and the price p_i was obtained as the average price $p_i = v_i/x_i$. A similar calculation was made to obtain the wage rate for labour. For capital there is no direct information available in the CME. The value v_i was obtained by subtracting all other costs from the value of output, and the user cost of capital (its p_i) was obtained extraneously from the National Income Forecasting (NIF) model data bank. This user cost of capital is the same for all establishments irrespective of industry, but varies over time.

The CME provides information on the value of expenditure on gas and electricity, but no information on prices or quantities. Another complication is that both fuels are sold to industrial customers according to a price schedule rather than at a given price, which implies that there is a distinction between the marginal and average price paid by each customer and a difference in these among customers. A third complication is the important distinction in pricing between the energy and demand components of the customers' usage of these fuels. An important part of the project was to use extraneous information, mainly on the pricing schedules, to break down a customer's total expenditure into demand and energy components and to then obtain the quantity of energy used and its associated marginal price. Thus, for the purposes of the econometric modelling we obtained for gas and electricity the quantity used x_i, the marginal price p_i, and the observed value of purchases v_i. Such marginal prices are needed, since it is well known from economic theory that it is the marginal price that is important in cost minimizing decisions on input choice and not average price.

The quantity of output y was obtained as the value of output divided by the price index of output, where the value of output is obtained from the CME and the price index of output is the "Price index for articles produced by manufacturing industry" as provided by ABS catalogue 6412.0. This index, indexed to be unity in 1968/69, varies over time and industry (subdivision).

4.4 **Fuel patterns**

The econometric modelling was performed separately on each of 9 empirically relevant patterns of fuel consumption. (With four fuels there are $2^4 = 16$ possible fuel patterns, each defined as a particular combination of fuels actually used, but some are not observed in practice.) These <u>fuel patterns</u> are defined by the fuels actually used by establishments and are described in the lower block of Table 4.2.

Table 4.3 provides information on the number of observations used in the econometric analysis, classified by fuel pattern and industrial subdivision. It is noted that pattern 8 alone has over 2/3 of the establishments. Pattern 8 is the one which includes electricity as the only fuel or energy source used. The other major patterns in terms of numbers of establishments are pattern 6 (oil and electricity) with 8031 observations, pattern 5 (gas and electricity) with 6898 observations, and pattern 2 (oil, gas and electricity) with 4130 observations. The other patterns have fewer than 1000 observations each. Indeed, pattern 9 has fewer than 100 observations and cannot be used in the estimation of model B. It is interesting to note that all four fuels are used in only 342 of the 64,952 observations. The conclusion is that there is a wide variety of fuel patterns actually used by establishments and that the econometric methodology employed needs to take this into account.

It is also interesting to note from Table 4.3 that there is a considerable spread of establishments within a particular industry subdivision over the various fuel patterns. That is, the different fuel patterns do not seem to be especially related to particular industry subdivisions. This suggests a diversity of technological conditions even within subdivisions.

It must be recognized in interpreting Table 4.3 that the number of establishments in a particular cell does not necessarily reflect accurately the importance of these establishments in the demand for energy since establishments differ substantially in size.

Table 4.4 provides information on the extent to which establishments remained in their initial fuel pattern or changed to alternative patterns over the period 1977/78 to 1984/85. The

Table 4.3 Numbers of establishments: by fuel pattern and industry

Industry	Fuel Pattern 1	2	3	4	5	6	7	8	9	Total
21	49	954	92	103	1011	1798	163	2204	5	6379
23	28	99	12	9	160	205	12	854	2	1381
24		59		2	166	370	3	3546	3	4149
25	2	104	8	11	222	774	13	6866	17	8017
26	7	209	8	3	586	559	9	6135	1	7517
27	28	374	19	11	574	526	7	1489	5	3033
28	41	304	21	79	377	705	58	1606	9	3200
29	90	386	32	24	293	255	41	337	3	1461
31	35	660	6	21	1230	1063	20	7742	20	10797
32	5	164	8	23	315	208	10	1985	2	2720
33	44	587	19	18	1256	1036	14	7787	7	10768
34	13	230	23		708	532	15	4005	4	5530
Total	342	4130	248	304	6898	8031	365	44556	78	64952

Table 4.4 Changes in fuel patterns, 1977/78-1984/85

Fuel Pattern	Percent unchanged	Most common fuel pattern destination (percentage)
1	74.85	3(11.11), 2(8.19)
2	75.43	5(13.46)
3	77.33	5(8.00), 3(7.33)
4	72.32	7(10.73) -
5	82.94	8(10.52)
6	77.02	8(13.21), 2(6.33)
7	78.60	4(6.51)
8	93.13	
9	30.77	8(11.54),6(50.00)

Note: a. The column "percent unchanged" is the percentage of establishments with that fuel pattern throughout the whole period.

b. The last column gives the most common fuel pattern destination of those establishments that did change their fuel patterns. The percentage of those initially in a particular fuel pattern is in parenthesis.

data refers to all establishments that could be tracked over the whole period and every change of pattern is recorded. The first column consists of percentages of establishments that did not change their fuel pattern over the period. This is over 72 percent for all fuel patterns except pattern 9. However, since this is the only fuel pattern without electricity use, it should be viewed very cautiously. On the other hand pattern 8 is very stable with 93 percent of "stayers". The table also gives the main pattern to which "movers" moved and the percentage of establishments involved.

While the percentage of "stayers" is quite high, there are significant numbers of movers. This aspect of the data, namely the movement between fuel patterns, is not one that is addressed in this report. It is an important issue and one that deserves serious investigation.

4.5 **Features of the data used in the econometric analysis**

Table 4.5 provides some information on the mean values of variables used in the estimation of the input cost share equations for model A. The means are based upon all observations in each fuel pattern and so represent an average over the whole 8-year period. The definitions of the variables are provided in Table 4.6.

The means for the D_k subdivision dummy variables give the proportion of the sample in subdivision k and so really express the information in Table 4.3 in proportion form.

Table 4.5 Sample means (by fuel pattern)

	1	2	3	4	5	6	7	8	9
LP_C	1.416	0.000	1.331	1.343	0.000	0.000	1.285	0.000	0.000
LP_O	2.380	2.503	0.000	2.535	0.000	2.603	0.000	0.000	2.660
LP_G	2.346	2.496	2.524	0.000	2.471	0.000	0.000	0.000	0.000
LP_E	3.585	3.714	3.601	3.619	3.794	3.814	3.690	3.936	0.000
LP_L	10.429	10.307	10.369	10.293	10.238	10.241	10.315	10.109	10.000
LY	14.344	13.036	13.730	13.069	12.477	12.069	12.813	11.174	11.147
D23	.082	.024	.048	.030	.023	.026	.033	.019	.026
D24	0.000	.014	0.000	.007	.024	.046	.008	.080	.038
D25	.006	.025	.032	.036	.032	.096	.036	.154	.218
D26	.020	.051	.032	.010	.085	.070	.025	.138	.013
D27	.082	.091	.077	.036	.083	.065	.019	.033	.064
D28	.120	.074	.085	.260	.055	.088	.159	.036	.115
D29	.263	.093	.129	.079	.042	.032	.112	.008	.038
D31	.102	.160	.024	.069	.178	.132	.055	.174	.256
D32	.015	.040	.032	.076	.046	.026	.027	.045	.026
D33	.129	.142	.077	.059	.182	.129	.038	.175	.090
D34	.038	.056	.093	0.000	.103	.066	.041	.090	.051
T	2.942	3.232	3.399	2.957	3.748	3.142	3.447	3.570	3.333
SH_C	.026	0.000	.022	.041	0.000	0.000	.048	0.000	0.000
SH_O	.012	.018	0.000	.021	0.000	.025	0.000	0.000	.040
SH_G	.011	.012	.010	0.000	.014	0.000	0.000	0.000	0.000
SH_E	.034	.026	.027	.033	.024	.021	.035	.016	0.000
SH_L	.516	.519	.557	.521	.544	.523	.514	.578	.544

Table 4.6 Definitions of variables

VARIABLE	DESCRIPTION
LP_C	Log of price of coal/price of capital
LP_O	Log of price of oil/price of capital
LP_G	Log of price of gas/price of capital
LP_E	Log of price of electricity/price of capital
LP_L	Log of price of labour/price of capital
LY	Log of output
D23	Industry 23 dummy
D24	Industry 24 dummy
D25	Industry 35 dummy
D26	Industry 26 dummy
D27	Industry 27 dummy
D28	Industry 28 dummy
D29	Industry 29 dummy
D31	Industry 31 dummy
D32	Industry 32 dummy
D33	Industry 33 dummy
D34	Industry 34 dummy
T	Time in years (1977/78=0)
SH_C	Cost share of coal
SH_O	Cost share of oil
SH_G	Cost share of gas
SH_E	Cost share of electricity
SH_L	Cost share of labour

The variable LY is the log of output (real). The log form was used in the estimation and so is appropriate to present here, but it should be noted that the log transformation compresses variations in the underlying variable. Thus, the apparent small variation in the mean of LY from 11.147 to 14.344 actually reflects a variation in output from 69,355 to 1,696,368.

The price variables represent the log of prices of the inputs shown relative to the (rental) price of capital, which is the same for all establishments in a particular year. Table 4.4 shows that (a) relative prices are reasonably even over the different fuel patterns as would be expected, and (b) that electricity is the most expensive energy form per gigajoule, coal is the cheapest, and gas and oil are about equally expensive.

The mean values for the observed input cost shares are presented in the bottom five rows of Table 4.5. While the cost shares for the fuels are relatively small, they also exhibit substantial variation across fuel patterns in which they appear. For example, electricity has a cost share of .035 in pattern 7 but it is only .016 in pattern 8. Of course, the shares of fuels in some patterns fall to zero.

The means presented in Table 4.5 are for all establishments with particular fuel patterns, irrespective of industry subdivision. The means of these variables may also be calculated for each subdivision irrespective of fuel pattern, and these are presented in Table 4.7. Each mean is calculated only over those observations for which the factor (price and share variables) is used. There is clearly substantial variation in the observed input cost shares across industry subdivisions. Although there also appears to be more relative price variation over subdivisions than over patterns, the variation in shares suggests that there are significant technological differences between subdivisions.

While it is instructive to examine the data in this way, such an examination lacks the structure of an econometric model. It is to the specification and then the estimation of such a model that attention is now turned.

Table 4.7 Sample means subdivision

	Subdivision											
	D21	D23	D24	D25	D26	D27	D28	D29	D31	D32	D33	D34
INTERCEP	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000	1.000
LP_C	1.133	.987	0.000	1.059	1.278	1.196	1.090	1.955	1.497	1.965	1.667	1.174
LP_O	2.430	2.479	2.571	2.700	2.712	2.390	2.593	2.370	2.639	2.643	2.716	2.599
LP_G	2.438	2.283	2.712	2.576	2.657	2.421	2.085	2.283	2.511	2.489	2.579	2.637
LP_E	3.748	3.848	3.951	3.902	3.918	3.826	3.839	3.784	3.928	3.894	3.916	3.883
LP_L	10.113	10.123	9.982	10.066	10.166	10.329	10.345	10.315	10.151	10.160	10.213	10.114
LY	12.155	12.071	11.577	11.117	11.357	12.524	11.664	12.634	11.150	11.747	11.657	11.580
T	3.439	3.434	3.397	3.573	3.631	3.505	3.448	3.427	3.543	3.477	3.465	3.508
SH_C	.020	.023	0.000	.033	.056	.023	.098	.047	.006	.004	.005	.066
SH_O	.034	.022	.005	.025	.005	.019	.045	.030	.016	.010	.006	.019
SH_G	.013	.015	.005	.005	.005	.014	.057	.020	.013	.006	.005	.006
SH_E	.034	.020	.011	.016	.013	.022	.024	.032	.015	.014	.013	.024
SH_L	.498	.558	.633	.572	.592	.433	.460	.503	.588	.598	.591	.554
OUTPUT	.267	.310	.121	.075	.107	.394	.189	.442	.081	.226	.148	.128

5. Empirical results: model A

5.1 Introduction

In this section the results obtained from the estimation of the first of the two main models considered are presented and discussed. This model, defined partially by equation (3.9), will be referred to as Model A. It requires that all of the parameters of the share equations, with the exception of the intercept parameters, are the same for all industry subdivisions but allows all of the share equation parameters to be different from one fuel pattern to another. Thus, the share equations exhibit limited differences between industries. On the other hand, the "non-price" parameters that do not appear in the share equations are the same for all patterns but differ by industry.

Because of the large number of parameters involved and the large number of elasticities that can be calculated (e.g. for each industry, year, and fuel pattern), only a portion of the full set of results can be presented and discussed in this report.

5.2 Pattern specific results

For each fuel pattern the model given by equation (3.9) was estimated by the method of maximum likelihood assuming that the disturbances are independently and identically distributed for each observation h as joint normal variables with zero mean and a constant covariance matrix. The parameter estimates are presented in Tables B.1.1-B.1.9 in Appendix B for the respective fuel patterns. These parameters may be directly interpreted in terms of equation (3.9). Each parameter represents the effect upon the share of an input of an increase in the explanatory variable corresponding to that parameter.

Table B.3 in Appendix B provides the system R-squared values for each of the fuel pattern estimations. This statistic gives an indication of how well the model predicts the input shares. It ranges from zero to unity with higher values indicating better predictions. The values reported in Table B.3 are similar in magnitude to those reported in most cross-section applications. The R-squared values reported range from 0.16 for patterns 6 to 0.59 for pattern 9.

Own-price elasticities

Of perhaps greater interest are the price effects, and these may be expressed more conveniently in terms of elasticities of demands for inputs with respect to prices. These elasticities, which are the percentage change in the demand for input i when the price of input j is increased by one percent and all other explanatory variables are unchanged, are given in Tables 5.1.1-5.1.9. They are evaluated at the sample means for the explanatory variables, and these have already been presented in Table 4.5. Thus they represent the elasticity for a "representative" or average establishment with that particular fuel use pattern.

The own-price elasticities of demand for each of the fuel patterns are brought together in Table 5.2 for ease of comparison. They represent the percentage change in the demand for each input as a result of a one percent increase in the price of that input, all other prices and output constant, for the "representative" establishment. As such, the elasticity is a good indication of the effect of a change in a price over all industries.

Table 5.1 Price elasticity matrices (Model A)

Table 5.1.1 Price Elasticity Matrix : Fuel Pattern 1

	COAL	OIL	GAS	ELEC	LAB	CAP
COAL	-.407	.056	.147	-.216	-.110	.531
OIL	.123	-2.302	.147	-.858	1.623	1.267
GAS	.345	.156	-2.908	-.048	.869	1.585
ELEC	-.164	-.293	-.015	-1.113	.979	.605
LAB	-.005	.036	.018	.064	-.220	.106
CAP	.034	.037	.043	.051	.136	-.301

Table 5.1.2 Price Elasticity Matrix : Fuel Pattern 2

	OIL	GAS	ELEC	LAB	CAP
OIL	-1.531	-.080	-.234	.451	1.394
GAS	-.120	-2.584	-.471	.825	2.350
ELEC	-.161	-.216	-1.710	.813	1.274
LAB	.015	.019	.040	-.364	.290
CAP	.058	.065	.077	.353	-.552

Table 5.1.3 Price Elasticity Matrix : Fuel Pattern 3

	COAL	GAS	ELEC	LAB	CAP
COAL	-.821	-.012	-.211	1.062	-.018
GAS	-.028	-3.870	-.210	1.465	2.643
ELEC	-.172	-.074	-1.530	1.894	-.118
LAB	.043	.025	-.093	-.420	.260
CAP	-.001	.066	-.008	.376	-.433

Table 5.1.4 Price Elasticity Matrix : Fuel Pattern 4

	COAL	OIL	ELEC	LAB	CAP
COAL	-.834	.144	-.185	.711	.165
OIL	.278	-1.713	-.219	.735	.919
ELEC	-.235	-.144	-.970	.819	.530
LAB	.056	.030	.051	-.306	.169
CAP	.018	.051	.045	.229	-.343

Table 5.1.5 Price Elasticity Matrix : Fuel Pattern 5

	GAS	ELEC	LAB	CAP
GAS	-2.487	-.535	1.261	1.761
ELEC	-.327	-1.745	.813	1.259
LAB	.033	.035	-.291	.222
CAP	.061	.071	.289	-.421

Table 5.1.6 Price Elasticity Matrix : Fuel Pattern 6

	OIL	ELEC	LAB	CAP
OIL	-1.458	-.174	.225	1.407
ELEC	-.207	-1.471	.466	1.212
LAB	.011	.019	-.264	.235
CAP	.081	.059	.285	-.425

Table 5.1.7 Price Elasticity Matrix : Fuel Pattern 7

	COAL	ELEC	LAB	CAP
COAL	-1.068	-.095	.630	.533
ELEC	-.131	-1.179	.642	.667
LAB	.059	.044	-.498	.395
CAP	.064	.059	.504	-.627

Table 5.1.8 Price Elasticity Matrix : Fuel Pattern 8

	ELEC	LAB	CAP
ELEC	-1.317	.375	.942
LAB	.010	-.118	.108
CAP	.037	.153	-.190

Table 5.1.9 Price Elasticity Matrix : Fuel Pattern 9

	OIL	LAB	CAP
OIL	-.825	.422	.402
LAB	.031	-.199	.168
CAP	.039	.220	-.259

To illustrate the nature of these elasticity estimates consider the results for pattern 1 in which all fuels are used. The own-price elasticities of demand for the fuel inputs are: coal (-0.4), oil (-2.3), gas (-2.9) and electricity (-1.1), while for the other inputs they are: labour (-0.2) and capital (-0.3).Thus, while coal, labour and capital have very inelastic own-price demands, oil, gas and, to a lesser extent, electricity have elastic demands.

The elasticity estimates are remarkably similar across the different fuel patterns, as can be seen from Table 5.2. While the numerical values of the estimates vary, the general results are that (i) coal has an inelastic demand, as do labour and capital, and that (ii) oil, gas and electricity have elastic demands. Of these, gas has the most elastic demand (varying between -2.5 and -3.9), while the elasticities for oil and electricity are typically between -1 and -2.

Cross-price elasticities

Cross-price elasticities of demand are also of interest. Consider, for example, the cross-price elasticities between gas and electricity. There are two elasticities, one defined for each price change (that is, the elasticity of demand for gas with respect to the price of electricity and the elasticity of the demand for electricity with respect to the price of gas), that may be (and generally will be) different in value but not in sign.

The elasticity of demand for gas with respect to the price of electricity (i.e. the percentage change in the demand for gas due to a one percent increase in the price of electricity) is -0.05 in pattern 1, -0.47 in pattern 2, -0.21 in pattern 3 and -0.53 in pattern 5. This elasticity is always negative and less than one in absolute value. The negative sign indicates that gas and electricity are complements. An increase in the price of electricity causes a reduction in the demand for gas as well as electricity. This is a rather surprising result since it would be expected that gas and electricity would be substitutes (positive cross-price elasticity). However, the elasticity estimate is fairly small. Another cross-elasticity of demand of special note is that between oil and electricity. This elasticity is always negative indicating that oil and electricity are complements also. These negative cross-price elasticities are counter-balanced by fairly strong positive substitution effects between these fuels and the primary factors labour and capital. Thus, substitution between fuels and the primary factors appears to be much stronger than between the fuels themselves.

Table 5.2 Own-price elasticities (Model A)

Fuel Pattern	COAL	OIL	GAS	ELEC	LAB	CAP
1	-.407	-2.302	-2.908	-1.113	-.220	-.301
2		-1.531	-2.584	-1.710	-.364	-.552
3	-.821		-3.870	-1.530	-.420	-.433
4	-.834	-1.713		-.970	-.306	-.343
5			-2.487	-1.745	-.291	-.421
6		-1.458		-1.471	-.264	-.425
7	-1.068			-1.179	-.498	-.627
8				-1.317	-.118	-.190
9		-.825			-.199	-.259

Output and time effects

The parameter estimates reported in Tables B.1.1-B.1.9 in Appendix B may be used to illustrate the effects of changes in output and time upon input shares. For example, consider the results for pattern 1. The coefficients of ln y denote the effect of a one percent change in output level y upon the shares of the various inputs. Thus, we see that as output increases while other explanatory variables constant, the cost shares of coal and capital increase, while the cost shares of oil, gas, electricity and labour decline. Larger output establishments tend to be more coal and capital intensive in their production process. The same sign effects of changes in output upon factor shares occurs for most of the other fuel patterns. The only exception to this sign structure is that the share of electricity increases in response to an increase in output in fuel patterns 4 and 7.

The time variable t is introduced to deal in an ad hoc, but commonly accepted, way with technical change. The coefficients of t in the regressions indicate the direction of bias in technical change. For pattern 1 we see that technical change (t) is gas, labour and capital saving in the sense that the cost shares for these inputs decline over time. Similarly, it is coal, oil and electricity using since the cost shares (at unchanged prices) for these inputs increase with time. The same direction of bias of technical change for the four fuels occurs in patterns 2 through 5, the only difference being that labour's share increases over time in 5 of the fuel patterns while capital's share rises in fuel pattern 7.

Industry effects

In the reported results the 2-digit ASIC industry effects occur through the industry dummy variables. Thus industries differ in the intercepts in the share equations but not in the other parameters. While there are too many parameters to allow a simple conclusion about industry effects, the importance of the coefficients of the industry dummy variables may be jointly tested statistically. The null hypothesis that there are no differences between industries (all industry dummy coefficients are zero) was soundly rejected in each fuel pattern.

General remarks

Similar statistical tests were undertaken to determine the importance of other variables. These were (a) fuel prices, (b) output, and (c) time. In each case the null hypothesis that these variables are irrelevant to the share equations (coefficients are zero) was soundly rejected. The conclusion is that input shares are significantly affected (statistically) by fuel prices, by output level, by time, and by industry.

The elasticity estimates presented in Table 5.1 conform to the economic theory of factor demand functions derived from the assumption of cost minimizing behaviour. According to that theory the demand for each input is a declining function of its own price: as price increases the quantity demanded falls. The negative elasticities in Table 5.2 confirm this.

Economic theory suggests that additional properties should hold, namely that the cost function is concave. It is, therefore, interesting to note that the estimate of the establishment cost function is concave in input prices for each fuel pattern, when evaluated at the sample mean values for the explanatory variables. Concavity is not imposed on the estimates by our choice of functional form, but has been checked. From a theoretical view point, concavity is an implication of cost minimizing behaviour. Accordingly, our results appear to be consistent with the hypothesis that establishments choose input quantities to minimize costs.

5.3 **Aggregate elasticities by ASIC subdivision**

Having considered the results for each separate fuel pattern, we now consider the results of interest for each ASIC industry subdivision. The results are most easily and directly evaluated in terms of the estimates of the various elasticities.

For each ASIC industry subdivision the effects of separate changes in the prices of the inputs, in outputs and the passage of time are calculated as a weighted average of the corresponding effects upon establishments in each fuel pattern. They represent the market elasticities and as such may be directly used to answer various "what if" questions and to provide forecasts of future input demands relative to a given base.

The changes in the exogenous variables are assumed to be relevant to all firms in each of the fuel pattern groups. Thus, all firms are assumed to experience the same percentage change in the price of oil, for example. Similarly, all firms are assumed to face the same percentage change in output. While all establishments are assumed to be subject to the same exogenous changes, they will react differently depending upon the industry they are in and upon the fuel pattern they have. This is because all the "price parameters" are different for each fuel pattern, and the intercepts of the share equations are different for each industry as are the "non-price parameters". If a fuel is not used in a particular fuel pattern, then its elasticities for firms in that pattern are identically zero. The total effect is a weighted average of all these separate effects.

The aggregate elasticities have been calculated for each of the 8 years in the sample and for each of the 12 ASIC subdivisions. The exogenous variables (prices and output) are evaluated at the weighted means for all firms in each industry in each year. While all these elasticity matrices (96 in all) are available, only the results for 1984/85 are considered in this report to facilitate ease of exposition.

The aggregate elasticity estimates for 1984/85 are presented in Tables 5.3 and 5.4. Table 5.3 contains the elasticities of primary interest, namely the own-price elasticities of demand, the output elasticities of demand, and the percentage rate of change in demands per annum.

Own-price elasticities

Consider the own-price elasticities of demand. Some significant patterns emerge from Table 5.3. First, apart from coal in some industries, all of the elasticity estimates are negative as expected from the economic theory of cost minimization. Second, the estimates of the own-price elasticities of demand for labour and capital are quite uniform and fairly low. They range from about -.2 to -.4, indicating fairly inelastic demands for the primary factors. Third, the most elastic demands are for oil, gas and electricity. The estimates of the elasticity of the demand for electricity with

Table 5.3 Elasticities for 1984/85: Own-price and output elasticities and time effects

	Industry subdivision											
	D21	D23	D24	D25	D26	D27	D28	D29	D31	D32	D33	D34
Own-price elasticities												
COAL	-1.055	-.918	-1.062	-1.062	-.983	-.851	-.869	-.902	-.916	-.787	-.782	-.863
OIL	-1.314	-1.394	-1.978	-1.384	-2.150	-1.511	-1.215	-1.407	-1.681	-1.861	-2.333	-1.526
GAS	-1.876	-2.540	-1.907	-1.999	-1.647	-1.643	-1.250	-1.651	-1.745	-2.320	-2.060	-1.998
ELEC	-1.253	-1.289	-1.520	-1.292	-1.359	-1.339	-1.218	-1.250	-1.416	-1.430	-1.486	-1.312
LAB	-.369	-.282	-.153	-.175	-.200	-.362	-.384	-.418	-.225	-.203	-.241	-.252
CAP	-.448	-.389	-.369	-.296	-.346	-.362	-.457	-.457	-.398	-.432	-.416	-.388
Output elasticities												
COAL	.245	1.233	1.523	-.043	1.230	-.181	1.204	.748	.118	.607	1.311	.483
OIL	-.171	.945	.605	-.481	.621	-.458	.955	.453	-.451	.216	.624	.201
GAS	-.112	.897	.791	-.455	.882	-.328	1.058	.568	-.273	.473	.961	.296
ELEC	-.038	1.050	.797	-.450	.883	-.300	1.076	.621	-.254	.554	1.031	.335
LAB	-.108	.960	.723	-.588	.772	-.382	.985	.580	-.343	.535	.970	.265
CAP	.069	1.141	.957	-.336	1.000	-.206	1.146	.730	-.124	.675	1.165	.456
Time rate of change												
COAL	.097	.079	.316	.024	.052	.058	.054	.094	.054	.184	.150	.061
OIL	.109	.067	.132	.092	.133	.071	.135	.122	.080	.104	.134	.080
GAS	.049	-.035	.048	.023	.046	.029	.107	.086	.016	.015	.055	.009
ELEC	.123	.105	.177	.134	.141	.112	.147	.155	.113	.169	.169	.118
LAB	.080	.068	.115	.110	.107	.067	.110	.104	.071	.088	.114	.083
CAP	.075	.055	.094	.083	.087	.060	.113	.103	.053	.091	.101	.069

Table 5.4 Elasticities for 1984/85: Cross-price elasticities

		Industry subdivision											
		D21	D23	D24	D25	D26	D27	D28	D29	D31	D32	D33	D34
COAL	OIL	.011	.005	.300	.004	.026	.065	.010	.011	.073	.110	.029	.001
COAL	GAS	.002	-.001	0.000	-.001	.012	.004	.010	.015	.018	-.004	.040	.003
COAL	ELEC	-.161	-.096	-.822	-.075	-.131	-.115	.011	-.056	-.280	-.346	-.274	-.079
COAL	LAB	.705	.798	1.389	.700	.659	.752	.509	.523	.713	1.296	.704	.813
COAL	CAP	.500	.212	.196	.434	.418	.145	.328	.408	.392	-.268	.283	.126
OIL	COAL	.004	.005	.002	.001	.005	.024	.017	.013	.007	.087	.006	.000
OIL	GAS	-.018	-.018	-.043	-.015	-.045	-.032	.009	-.025	-.049	-.068	-.111	-.041
OIL	ELEC	-.112	-.145	-.401	-.143	-.462	-.194	-.070	-.149	-.281	-.341	-.580	-.206
OIL	LAB	.346	.367	.216	.346	.042	.290	.380	.387	.350	.600	.196	.362
OIL	CAP	1.094	1.185	2.205	1.195	2.610	1.423	.880	1.181	1.654	1.583	2.820	1.410
GAS	COAL	.001	-.001	0.000	-.000	.001	.001	.009	.012	.001	-.002	.003	.001
GAS	OIL	-.026	-.021	-.034	-.029	-.012	-.018	.005	-.016	-.024	-.046	-.036	-.023
GAS	ELEC	-.223	-.348	-.290	-.303	-.198	-.169	-.040	-.131	-.227	-.298	-.323	-.259
GAS	LAB	.751	1.036	.993	.925	.854	.632	.566	.629	.840	1.063	.956	.929
GAS	CAP	1.373	1.874	1.238	1.406	1.003	1.198	.709	1.158	1.156	1.603	1.460	1.350
ELEC	COAL	-.022	-.024	-.001	-.003	-.002	-.013	.008	-.020	-.006	-.068	-.008	-.009
ELEC	OIL	-.043	-.033	-.102	-.037	-.049	-.058	-.030	-.044	-.063	-.084	-.078	-.037
ELEC	GAS	-.059	-.070	-.095	-.040	-.077	-.088	-.030	-.061	-.104	-.107	-.134	-.081
ELEC	LAB	.593	.718	.678	.537	.607	.565	.584	.619	.661	1.014	.716	.699
ELEC	CAP	.783	.697	1.040	.835	.880	.932	.686	.756	.929	.675	.990	.739
LAB	COAL	.009	.014	.000	.001	.001	.008	.038	.021	.001	.011	.001	.006
LAB	OIL	.013	.006	.002	.004	.000	.008	.018	.013	.004	.006	.001	.004
LAB	GAS	.019	.014	.010	.006	.016	.030	.046	.035	.018	.017	.018	.019
LAB	ELEC	.057	.050	.020	.024	.029	.052	.064	.073	.032	.044	.033	.047
LAB	CAP	.271	.198	.121	.140	.154	.265	.219	.276	.170	.125	.189	.176
CAP	COAL	.007	.005	.000	.001	.001	.001	.027	.016	.001	-.005	.001	.001
CAP	OIL	.042	.024	.034	.020	.020	.031	.045	.039	.028	.037	.026	.024
CAP	GAS	.036	.034	.025	.012	.028	.046	.063	.060	.039	.055	.041	.040
CAP	ELEC	.078	.064	.064	.056	.064	.069	.082	.083	.069	.065	.067	.071
CAP	LAB	.284	.262	.246	.207	.233	.214	.239	.260	.262	.279	.281	.252

respect to its own price are uniformly above unity in absolute value and range from about -1.2 to -1.4. Thus, a 1 percent increase in the (marginal) price of electricity is estimated to cause a 1.2 to 1.4 percent fall in the demand for electricity. The estimates of the own-price elasticities of demand for gas and for oil are more variable with both, ranging from about -1.2 to -2.3. Clearly, the elasticity depends crucially upon the industry. Finally, the own-price elasticity for coal is generally lower than unity in absolute value. However, the relatively small numbers of establishments using coal means that limited faith should be placed on its price elasticity.

Output elasticities

The output elasticities are presented in the next block of rows in Table 5.3. They represent the percentage change in demands due to a one percent increase in output (real), other exogenous variables (prices and time) being held constant. Normal expectation is that these elasticities will be positive. However, economic theory does not rule out some negative elasticities, which imply that these inputs are "inferior". Nevertheless, there are probably more negative estimates than is reasonable. Indeed there are two industries (D25 and D27) that have all output elasticities negative. Part of the reason may be the difficulty of obtaining suitable indices of real output in industries containing a variety of firms producing multiple outputs.

Some other features of the output elasticities worthy of note are as follows. First, industries D21, D25, D27, D29, D31, D32 and D34 have all output elasticities less than unity (with some negatives in some industries), indicating increasing returns to scale. In these cases a one percent increase in output causes a smaller percentage increase (some times a decrease) in the demands for all inputs. Second, all other industries exhibit a mix of elasticities - some greater and some less than unity. If the output elasticities for all inputs exceed unity there are definitely decreasing returns to scale in production. When there is a mix of elasticities greater and less than unity the nature of returns to scale is unclear. To be precise we have that the percentage change in cost due to a one percent change in output is

$$\partial \ln C / \partial \ln y = \sum_{i=1}^{n} s_i \, \partial \ln x_i / \partial \ln y.$$

Thus, returns to scale will be increasing if this expression is less than unity, that is, the share weighted average of the output elasticities is less than unity. Since the cost shares for the fuels are small, it is the elasticities for labour and capital that dominate this calculation. On this basis subdivisions D23, D28 and D33 would appear to have approximately constant returns to scale.

Time effects

The third block of results in Table 5.3 are the percentage changes in demands for factors per year, keeping prices and output constant. This is meant to be interpreted as the effect of exogenous technical change, but it should more accurately be interpreted as the effect of all variables (other than price and output) that affect demands and are correlated with time. All (except one) estimates of this effect are between zero and unity, and are typically close to zero. In subdivision D21, for example, it is estimated that there will be approximately a .1

percent increase in the demand for most inputs per year. The technical change interpretation of these estimates would require that they be negative, indicating a reduction in demand for inputs with the passage of time.

The occurrence of many negative output elasticities and of positive rates of change over time is of some concern. Mention has already been made of the potential problems with the construction of the real output variable for establishments. The time variable is, of course, picking up the effects of all influences other than prices, output (as measured) and industry that are correlated with time. It may also be the case that the response of inputs to output is more nonlinear than the adopted specification allows, and this additional effect is being absorbed by the time variable. However, the opportunity to investigate these possibilities did not exist.

Cross-price elasticities

The cross-price elasticity estimates are presented in Table 5.4 for each ASIC subdivision. Of the 30 different elasticities the ones relating to relationships between the four fuels and their prices are of primary interest. Consistent sign patterns over the various subdivisions are as follows. Coal and electricity are estimated to be complements, with a negative elasticity indicating that an increase in the price of one will cause a reduction in the demand for the other. Similarly, oil and electricity are estimated to be complements in all subdivisions, as are gas and electricity. Gas and oil are also generally complements. Coal is predominantly a substitute for oil and gas.

These results may be summarized in stylized form as follows. The sign of the matrix of cross-elasticities of demands for fuels appears to be:

	C	O	G	E
C	-	+	+?	-?
O		-	-?	-
G			-	-
E				-

where a "-" denotes a negative estimate for all subdivisions, a "-?" denotes a negative estimate for most subdivisions, and a "?" denotes that both signs occur frequently.

6. **Empirical results: model B**

6.1 **Introduction**

Model B is defined partially by equation system (3.10). It allows all of the parameters of the input cost share equations to be different for each of the nine fuel patterns and twelve industry subdivisions. Thus, there are share equations that may exhibit substantial differences between industries (as well as fuel patterns). Moreover, as in model A, the "non-price" parameters are assumed to be the same for all fuel patterns within a particular industry, but these parameters may be arbitrarily different between industries. In short, model B allows totally different technologies in the various industry subdivisions.

6.2 **Pattern specific results**

The parameters of the share equations are different for each fuel pattern and industry subdivision in model B, so there are too many parameter estimates to present in this report. However, as an indication of the explanatory power of each set of share equations the system R-squared values are presented in Table B.4 in Appendix B. The system R-squared values vary substantially and range from 0.06 (subdivision 24, fuel pattern 8) to 0.99 (subdivision 26, fuel pattern 7). However, most are in the vicinity of 0.2 to 0.6, which compares favourably with other cross-section studies.

Because there were too few observations in a number of subdivision/fuel-pattern combinations, no estimations were performed in such cases. These are indicated by blank entries in Table B.4. Accordingly, these subdivision/fuel-pattern combinations are not relevant to the results presented in this section of the report.

A summary of the own-price elasticities of demand for the inputs for each fuel pattern and industry subdivision is provided in Table 6.1. These elasticities are evaluated at the sample means over all observations in the corresponding sub-sample. Since there are 80 combinations of fuel pattern and industry subdivision for which sufficient observations existed for estimation, Table 6.1 merely presents the range of elasticities obtained for each fuel pattern.

Table 6.1 shows that the own-price elasticity estimates for labour and capital are generally quite low in absolute terms, while those for the four energy types are larger and more variable. The estimates for coal become positive quite often, and these estimates should be viewed with caution. The estimates for oil, gas and electricity are generally negative and mostly less than minus unity, indicating elastic demands.

It is interesting to consider the extent to which the empirically estimated price elasticity matrix satisfies the conditions required by economic theory. The condition that the cost function be concave in input prices was checked. Of the 80 cases to consider, the concavity condition (at the sample mean) was violated in only 20 cases. This is quite reassuring as the condition is very strict and the functional form being used is very flexible. A less stringent theoretical requirement is that all own-price elasticities be negative (or zero). Of the 349 cases to consider, this negativity condition was violated in just 20 cases. Accordingly, we conclude that the conditions of

Table 6.1 Own-price elasticities (Model B)
(ranges of estimates)

Fuel Pattern	COAL		OIL		GAS		ELEC		LAB		CAP	
1	-5.04	2.31	-1.89	.604	-3.56	0.74	-1.88	-.28	-.948	.001	-1.34	.016
2			-2.34	-.400	-3.52	-1.97	-2.60	-.84	-.840	-.081	-1.20	-.074
3	-1.46	2.13			-3.75	.405	-2.02	-.65	-.985	-.101	-2.30	.266
4	-1.10	.57	-3.08	.850			-1.64	3.73	-1.196	.195	-1.83	.667
5					-4.21	-1.38	-2.65	-1.00	-.500	-.193	-1.13	-.170
6			-1.93	-.739			-2.39	-.65	-.710	-.045	-.85	-.039
7	-2.97	2.10					-2.06	2.33	-1.011	-.037	-1.53	.081
8							-4.17	-.29	-.407	-.006	-.44	-.037
9												

Note: A blank entry denotes that the fuel is not used in that particular fuel pattern.
There are no entries for fuel pattern 9, since there were too few establishments in each industry to enable estimation of the share equation system.

Table 6.2 Elasticities for 1984/85: Own-price and output elasticities and time effects

	Industry subdivision											
	D21	D23	D24	D25	D26	D27	D28	D29	D31	D32	D33	D34
Own-price elasticities												
COAL	-2.760	-.803	0.000	-1.708	-2.480	.959	-.865	-.777	-.813	-.841	-.901	-2.124
OIL	-.985	-.695	-.527	-1.744	-1.355	-.858	-1.869	-1.288	-1.656	-.029	-1.522	-2.041
GAS	-1.727	-1.068	-1.536	-1.588	-1.467	-1.327	-3.039	-.638	-1.638	-1.571	-1.565	-1.656
ELEC	-1.596	-1.343	-1.164	-1.607	-1.109	-.170	-.517	-1.326	-1.435	-1.481	-1.406	-1.549
LAB	-.560	-.818	-.444	-.206	-.199	-.864	-.485	-.984	-.319	-.468	-.225	-.224
CAP	-.746	-1.556	-1.234	-.303	-.271	-2.746	-3.188	-.748	-.567	-1.168	-.319	-.298
Output elasticities												
COAL	.116	-1.679	0.000	-1.259	-1.934	1.804	.714	.800	.273	.886	.860	-.071
OIL	-.976	-1.795	.760	-.625	.944	-.225	.603	.785	-.092	.081	.677	.030
GAS	-.584	-1.567	1.338	-.385	.924	-2.378	.614	1.379	.033	.005	.785	.396
ELEC	-.461	-1.709	1.239	-.550	1.023	.956	1.001	.920	.088	.802	.790	.228
LAB	-.320	-1.536	1.234	-.656	.847	.112	.870	.557	.081	.204	.755	.231
CAP	-.226	-1.494	1.484	-.326	1.060	-1.634	1.032	.817	.262	.298	.894	.586
Time rate of change												
COAL	-.069	-.009	0.000	-.272	-.129	-.301	-.054	.177	-.005	-.018	.151	.544
OIL	.105	-.017	-.034	.182	.144	-.804	.081	.163	.050	-.472	.188	.189
GAS	-.094	-.070	-.071	.180	.094	-.689	.090	.377	.004	-.105	.086	.040
ELEC	.044	.038	.021	.234	.209	-.727	.165	.253	.111	-.043	.183	.198
LAB	-.127	.009	-.036	.142	.149	-.759	-.005	.165	.074	-.209	.159	.064
CAP	-.073	.071	-.012	.134	.128	-.293	.039	.156	.076	-.052	.140	.076

Table 6.3 Elasticities for 1984/85: Cross-price elasticities

		Industry subdivision											
		D21	D23	D24	D25	D26	D27	D28	D29	D31	D32	D33	D34
COAL	OIL	-.053	.250	0.000	-.134	0.000	.627	.001	.002	-.008	-.032	.213	0.000
COAL	GAS	.016	.117	0.000	0.000	0.000	.000	.453	-.025	.053	0.000	.017	-.051
COAL	ELEC	-.159	-.473	0.000	1.021	-4.167	.961	.048	-.075	-.055	.052	-.871	.000
COAL	LAB	1.364	.686	0.000	-1.053	-1.656	3.501	-.775	.732	.115	.700	.343	3.146
COAL	CAP	1.591	.223	0.000	1.875	8.303	-6.047	1.138	.143	.707	.120	1.199	-.971
OIL	COAL	-.113	.460	0.000	.040	0.000	.765	.024	.073	.000	.227	.011	0.000
OIL	GAS	.110	.015	.096	.002	.058	.000	.023	-.025	-.062	-.001	-.291	-.069
OIL	ELEC	-.219	-.115	-.288	-.345	-.348	.074	-.074	-.129	-.434	-.136	-.453	-.479
OIL	LAB	1.138	.218	.905	.412	.600	-1.175	-.016	.356	.646	.624	.475	1.135
OIL	CAP	.070	.117	-.187	1.634	1.044	1.194	1.913	1.013	1.507	-.684	1.780	1.455
GAS	COAL	.039	.284	0.000	0.000	0.000	.023	.584	-.121	.000	0.000	.000	-.017
GAS	OIL	.124	.020	.039	.005	.005	.059	.002	-.004	-.016	-.017	-.072	-.031
GAS	ELEC	.188	.180	-.204	-.327	-.188	-.260	.084	.379	-.187	-.257	-.417	.047
GAS	LAB	.902	-1.088	.777	.643	.843	-.043	.453	1.137	.807	.696	.795	.941
GAS	CAP	.473	1.672	.924	1.266	.807	1.547	1.916	-.752	1.034	1.149	1.259	.716
ELEC	COAL	-.068	-.406	0.000	-.138	.008	1.516	.210	-.137	.000	.056	-.006	.000
ELEC	OIL	-.044	-.054	-.134	-.157	-.026	.096	-.018	-.008	-.176	.021	-.064	-.092
ELEC	GAS	.033	.063	-.232	-.062	-.163	.000	.287	.142	-.299	.003	-.238	.020
ELEC	LAB	.691	.988	.997	.587	.495	-1.507	.764	.675	.641	.852	.695	.931
ELEC	CAP	.984	.752	.532	1.377	.794	.065	-.726	.654	1.270	.550	1.019	.690
LAB	COAL	.029	.029	0.000	.005	.000	.146	-.112	.120	.000	-.033	.000	.018
LAB	OIL	.011	.005	.008	.006	.001	-.040	-.000	.002	.010	.004	.002	.008
LAB	GAS	.008	-.019	.017	.004	.019	.000	.051	.038	.049	.000	.013	.016
LAB	ELEC	.034	.049	.019	.020	.013	-.040	.025	.060	.025	-.038	.020	.036
LAB	CAP	.478	.754	.401	.171	.166	.798	.521	.764	.235	.535	.190	.146
CAP	COAL	.044	.018	0.000	-.011	-.001	-1.179	.588	.021	.000	-.013	.000	-.009
CAP	OIL	.001	.005	-.005	.031	.003	.191	.054	.005	.036	-.011	.009	.017
CAP	GAS	.005	.055	.057	.010	.024	.000	.768	-.023	.097	.001	.027	.019
CAP	ELEC	.064	.070	.029	.058	.027	.008	-.086	.053	.075	-.057	.038	.042
CAP	LAB	.632	1.409	1.152	.214	.219	3.726	1.862	.692	.360	1.247	.246	.229

economic theory relating to the properties of the estimates of the cost functions with respect to input prices are met in the majority of instances.

6.3 **Aggregate elasticities by ASIC subdivision**

In section 5.3 aggregate elasticities of demand for the inputs from model A were presented and discussed for each of the twelve ASIC 2-digit subdivisions. In this section corresponding aggregate elasticities derived from the estimation of model B are presented and briefly discussed. It will be recalled that model B allows the "price parameters" - the parameters in the share equations - to be completely different between industries. It is therefore expected that the resulting elasticity estimates will exhibit greater variability across subdivisions than occurred for model A.

The aggregate elasticities of demand for each input with respect to its own-price and with respect to output, as well as the time rates of change for 1984/85 are presented in Table 6.2. As expected, these estimates do exhibit more variation than those for model A.

Consider the own-price elasticities of demand. With just one exception (coal in subdivision D27) all the own-price elasticities are negative. While the estimates for labour and capital are still generally low, there now appear several industries (D23, D24, D27, D28, and D32) where the own-price elasticity for capital is estimated to be elastic. For gas and electricity the own-price elasticity estimates are generally in excess of unity in absolute value indicating elastic demands, but several exceptions now arise. Thus, it is noted that the elasticity for electricity is quite low in D27 and D28, while D29 exhibits a low own-price elasticity of demand for gas. The results for coal and oil are more variable over subdivisions. The demand for coal is elastic in 4 out of 12 subdivisions, while oil is elastic in 7 subdivisions.

The general conclusion reached in section 5.2 remains true. Specifically, the demands for gas and electricity, and to a lesser extent oil are generally elastic. By contrast, the demands for labour and capital are generally inelastic.

The output elasticities appear lower than for model A, and have more negative estimates. On the other hand, the estimates of the time rates of change in the inputs are now negative for a large number of cases. In two industries (D27 and D32) all of the time rates of change are negative indicating a reduction in the inputs per unit of output over time, independent of changes due to changing prices and output.

The aggregate cross-price elasticity estimates are presented in Table 6.3. The uniformities across subdivisions that were observed for model A are lost somewhat in model B. However, oil and electricity are seen to be complements (negative cross-price elasticity estimate) in all but one subdivision, and gas and electricity remain as complements in 7 of the 12 industries.

Generally, the cross-price elasticities between energy types are fairly low and often negative. On the other hand, they are often more highly substitutable with the primary factors labour and capital.

7. Discussion of results

7.1 Introduction

In this section various issues are discussed. First, the results presented in sections 5 and 6 are discussed in relation to those elasticities presented in other studies of industrial energy demand. Then the question of how the results may be used to help facilitate provision of policy analyses and forecasts of future energy demand is briefly addressed.

7.2 Comparison with other studies

The own-price elasticities presented in Tables 5.3 and 6.2 may be compared with those obtained from other studies, both on Australian data and overseas data. Before proceeding to undertake this comparison it is prudent to mention some words of caution with the interpretation of such exercises.

First, elasticities are calculated at particular values for the exogenous variables (here these are the input prices, output and time) and they vary with variations in the values of these variables. To illustrate, a straight line demand function will have an elasticity varying from minus infinity to zero as one increases the price upwards from zero. Since researchers are unlikely to be choosing the same values for the exogenous variables, differences between estimates are to be expected.

Second, usually only point estimates of elasticities are presented (as in this report). The estimator is, however, random with a mean and variance. Since variances for the estimates of elasticities are seldom presented it is unclear how much confidence to place in point estimates of elasticities.

Third, elasticities may be defined under various assumptions about what is being held fixed. Consequently, two estimates may correspond to different conceptual experiments. They therefore cannot be compared. Fortunately, there is substantial uniformity in the literature in this regard and most own-price elasticities, for example, are based upon the assumption that all other input prices, output and time are held constant (as in the present study).

With these cautions in mind, consider a comparison of the results in Tables 5.3 and 6.2 with those presented in Table 7.1. This includes a selection of available estimates from Australia and overseas. A more detailed comparison may be made by reference to Bohi and Zimmerman [1984], who attempt to synthesize the elasticity estimates from a host of studies of energy demand.

Basically, Bohi and Zimmerman conclude that there is no concensus on estimates of own-price elasticities for the industrial demands for fuels. However, an examination of Table 7.1 indicates that electricity appears to have an inelastic demand at the aggregate level, though exceptions occur for individual industries. The demands for gas and oil appear to be elastic quite often. This conclusion is also supported by overseas studies.

The results presented in the current study contain larger (in absolute terms) elasticities than those in the literature. Thus, electricity and gas often have elastic demands, as does oil (though to a lesser extent). Perhaps it is the high estimated elasticity of the demand for electricity that is the most surprising and significant outcome of the present study.

Table 7.1 Own-price elasticity estimates from other studies

	COAL	OIL	GAS	ELEC
Australian studies				
Turnovsky, et al [1982]				
Australian manufacturing	-1.01	-1.09	-1.47	-0.60
Duncan & Binswanger [1976]				
Australian manufacturing				
Skins, leather	.90	-2.44	-2.08	-0.11
Sawmills	-.59	.03		-0.66
Furniture		1.13	-2.89	.01
Rubber	2.78	-1.21	.02	.51
Miscellaneous	-1.45	-0.46	-1.90	-0.31
Hawkins [1978]				
Australian manufacturing				
Group 1	-0.04	-0.61		2.43
2	-1.12	-1.08		.41
3	-0.86	-0.58		.66
4	-0.52	.15		2.85
5	1.05	-0.83		-1.37
Donnelly [1987]				
Australian manufacturing	-0.83	-1.03	-1.46	-0.40
Australian iron and steel	-0.29	-0.34	-0.31	-1.08
Overseas studies				
Magnus & Woodland [1986]				
Netherlands manufacturing	-0.64	-0.37	-0.98	-0.12
Halvorsen [1977]				
US manufacturing	-1.52	-2.82	-1.47	-0.92
Griffin [1977]				
OECD countries	-0.57	-3.12	-0.94	
Pindyck [1979]				
OECD countries	-1.29 to -2.24	-0.06 to -1.03	-0.41 to -2.34	-0.54 to -0.63
Fuss [1977]				
Ontario, Canada, manufacturing	-1.48	-1.3/1.59	-1.3/-2.39	-0.74

One potential qualification to the results relates to the fact that natural gas only became available in significant quantities in 1976. After that period - the period covered in this study - one would expect a rise in the market penetration of gas simply through its availability. Thus, it may be argued that these earlier quantity constraints and/or later market penetration effects are being picked up by the other variables such as price and time. The result might be that the estimate of the price elasticity of demand for gas is higher than it should be. While there may well be some truth in this, it is also true that the price may adequately reflect the supply constraints and so this source of bias, while possible, is not regarded as being very serious.

One difference between this and other studies is that the present study uses the marginal price as an explanatory variable. On this basis the present model specification is more appropriate to the problem, and as a consequence it is quite possible that better estimates of the elasticity of demand are being obtained.

7.3 **Forecasting industrial energy demand**

In this study the demand by an individual establishment for each of the four energy inputs is specified as a function of several exogenous variables. These input demand functions were assumed to have a particular (translog) functional form with parameters that were estimated econometrically using the extensive CME data set. These parameter estimates form one important input to the task of forecasting future industrial demands for energy.

General aspects of forecasting

The exogenous variables form the other crucial input for this task. These exogenous variables are the prices of each of the energy inputs, the wage rate for labour, the rental rate for capital, the required level of output, the industry dummy variables indicating the subdivision in which the establishment occurs, and the index of the state of technology given by time. The model specifies that energy demands at time (year) t depend upon the values of the exogenous variables (through the parameters and the functional form) at the same time t. It therefore follows that a forecast of future energy demands can only be obtained from the model if future forecasts of the values of each of the exogenous variables are available.

The only exogenous variables that can be forecast easily and with accuracy are the industry dummy variables and the time variable. The input price and output quantity variables have to be forecast as a separate independent exercise. Such forecasts may be obtained from (a) a separate econometric model, (b) a pure time-series modelling exercise in which the current value of an exogenous variable is some function if its past values, or (c) as guesstimates created for the purpose of 'scenario' simulations.

The resulting forecasts of the endogenous variables - the demands for the four energy types - will depend upon the parameter estimates and the forecasts of the exogenous variables. The quality of these forecasts clearly depends upon the quality of the parameter estimates and the exogenous variable forecasts. In particular, since both of these contain sampling variability so too will the forecasts of energy demands.

With these general observations on forecasting in mind, further detail regarding the use of the results of this study for forecasting is now provided.

Forecasting with parameter estimates

The model used in this study specifies the demand for input i by an establishment that exhibits fuel pattern j to be a function of the price vector for all inputs, the level of output and time as

$$(7.1) \quad x_i = \phi_{ij}(p, y_j, t; \beta)$$

where β denotes the vector of parameters. Here we consider an establishment in a particular industry and so do not explicitly include an industry notation. The aggregate demand for input i in the whole industry (aggregating over all of the 9 possible fuel patterns), assuming that all firms in a particular fuel pattern are the same (or, the establishment is representative for that fuel pattern), is

$$(7.2) \quad X_i \equiv = \sum_{j=1}^{9} n_j . \phi_{ij}(p, y_j, t; \beta)$$

where n_j is the number of establishments in that industry subdivision with fuel pattern j.

To provide an estimate (prediction) for X_i at some future time we need to know all components on the right hand side of (7.2). The functional form ϕ_{ij} is taken as provided by the translog formulation of section 3. The parameter vector β is replaced by its estimate, provided by the econometric estimation of the model. The numbers of establishments n_j are needed since the model provides demand functions for representative establishments (using data for establishments) in particular fuel patterns not the industry. The time variable t is clearly given by the choice of year for which the prediction is required.

The forecaster must have a prediction of the price vector p and the average industry output y_j in each fuel pattern to complete the forecast. Although the estimation of the model made use of establishment-specific values of p and y, such information is unlikely to be available to the forecaster. Accordingly, it is implicitly assumed that the forecaster knows (or predicts) the price vector p and the industry output level Y. It is then further assumed that all establishments face the same price vector p, and that the industry output level Y is evenly distributed among the industry's establishments so each has output level $y_j = y \equiv Y/n$, where n is the total number of establishments in the industry.

Alternatively, the forecaster might assume that aggregate industry output Y is distributed between the different fuel patterns in the same way as was observed in the data used in this study. Thus, if the proportion of total output Y occurring in fuel pattern j is α_j then we would calculate output in fuel pattern j as $Y_j = \alpha_j Y$ and average output in fuel pattern j as $y_j = Y_j/n_j$, which would be used as the output variable.

The above discussion relates to the problem of predicting the demand X_i for input i at some future date using predictions of the exogenous variables. This requires the calculations of predictions for each fuel pattern, weighting by the number of establishments in that pattern, and summing over the nine fuel patterns. The information needed consists of: the parameter estimates, the price vector p, the industry output level Y and the output distribution parameters α_j's.

Forecasting with aggregate elasticities

There exists an alternative forecasting method that does not require as much calculation or detailed knowledge regarding the data on the part of the forecaster. This method makes use of the full set of elasticities of aggregate industry demands with respect to all of the explanatory variables as evaluated at the most recent year. These elasticities are based upon (7.2) and are of the form

$$(7.3) \quad \partial \ln X_i/\partial\theta_k = \sum_{i=1}^{9} w_{ij}\ \partial \ln \phi_{ij}/\partial\theta_k$$

where the weights for the nine different fuel patterns are given by $w_{ij} = \phi_{ij}/X_i$. Here θ_k can be any explanatory variable.

Rather than use (7.2) directly to predict X_i at some future date, the alternative approach is to approximate the logarithm of (7.2) linearly about an initial point (indicated by superscript ^{o}) as

$$(7.4) \quad \ln X_i \approx \ln X_i^o + \sum_{k=1}^{n} [\partial \ln X_i/\partial \ln p_k]^o d\ln p_k + [\partial \ln X_i/\partial \ln Y]^o d\ln Y + [\partial \ln X_i/\partial t]^o dt$$

Thus the logarithm of the demand for input i at some new (p,Y,t) point is what it was at the reference point (p^o,Y^o,t^o) plus additional amounts (possibly negative) which are calculated as in (7.4). These depend upon all the elasticities evaluated at the reference point (the terms in square brackets) and the changes in the explanatory variables. For prices and outputs these are given as percentage changes, that is as changes in the logs of variables.

For short term forecasting this alternative method has much to recommend it. The forecaster need not know the parameter estimates, the functional forms, or the distribution of output between the fuel patterns. Only the aggregate elasticities, the base period values of the explanatory variables, and the postulated changes in the explanatory variables are needed. This information is used in (7.4) to generate changes in the X_i and hence forecasts of the X_i variables themselves.

Of course, this virtue of the method may also be its deficiency. The difficulty with using (7.4) for forecasting is that (7.4) is only valid in a "sufficiently small" neighbourhood of the reference point. As one moves away from this point the errors of approximation are likely to get larger. If this is suspected, the elasticity matrices should be re-calculated at the most recent prediction point. This, of course, requires further calculation and knowledge of the model's basic parameters.

Illustrative example

As an illustration of the method of forecasting changes in the demands for inputs using relationship (7.4), consider the case of subdivision D21. Over the 8-year period 1977/78 to

1984/85 the average percentage increases in the input prices and output and the change in t per year were:

Coal	14.24	Oil	50.19
Gas	11.24	Electricity	14.14
Labour	10.83	Capital	21.33
Output	-0.51	Time	1.0

These are the rough (because the changes are large) discrete approximations to $d\ln p_k$, $d\ln Y$ and dt which appear in (7.4). The elasticities appearing in square brackets in equation (7.4) are taken to be those evaluated at 1984/85 values for the exogenous variables. They are recorded in Tables 6.2 and 6.3 in the columns labelled D21. Substituting these data into equation (7.4) yields the predicted percentage changes (per year) in the input demands and these are recorded, along with the actual percentage changes, in Table 7.2.

Table 7.2 Predicted and actual percentage changes in input demands in subdivision 21, 1977/78-1984/85

	Average percentage changes per year	
Input	Actual	Predicted
Coal	-4.10	1.51
Oil	-10.08	-40.42
Gas	22.99	12.00
Electricity	3.03	2.43
Labour	-2.03	3.71
Capital	-3.02	-2.72

The results of this exercise are somewhat mixed in success. The predicted average percentage changes in demand for electricity and capital are fairly close to the actual changes. The direction of change for oil and gas are correctly predicted but the predicted and actual changes differ in magnitude. For coal and labour the directions of change are incorrectly predicted. However, it must be emphasized that this exercise is for illustration only, and since it involves large percentage changes in the exogenous variables and uses the end-of-period elasticity matrix, it therefore constitutes a somewhat rough test of the model. Clearly, a more careful testing of the predictive power of the models estimated in this report will need to be undertaken.

8. **Conclusion**

This study appears to be the first known analysis of the demands for coal, oil, gas and electricity using data at the level of the establishment. Certainly, it is the first such analysis of the NSW Census of Manufacturing data at the establishment level.

The opportunity of analyzing such an extensive set of data at the level of the establishment is particularly good, because it enables the use of vastly more observations than the use of aggregated data. Moreover, it enables a closer relationship between the theoretical models and the empirical variables used.

Much effort was put into the proper construction of variables used in the econometric analysis. That analysis was limited in scope by the time and resource constraints of the project. There are many extensions of the project that could and, in my view, should be undertaken. The detailed work done on the data should certainly be retained to ensure that any future work or extension of the present project may proceed without the large set-up costs relating to the data. It would be a pity if such a valuable research resource was not maintained for future use.

As indicated in this report, considerable effort was expended in deriving estimates of the quantities of gas and of electricity used by establishments. The methodology for this may well be of particular interest to others faced with the problem of constructing a data base suitable to describe the industrial demands for energy and to undertake an econometric analysis. It is surprising that the ABS does not collect information on the quantities of gas and electricity used by establishments. This is clearly an area where the Census of Manufacturing data base could be dramatically improved.

The current project has been devoted to an econometric analysis of the demands for coal, oil, gas, electricity and other inputs (labour and capital) by establishments in NSW manufacturing industries. The results concerning the price elasticities of demand were estimated quite well, and there was considerable uniformity over industries and specification. The results concerning the effects of output and time changes upon the demands for energy, on the other hand, suggest that more work needs to be done on constructing more appropriate price indices for output.

Overall, the results of the project should provide a very useful input to the forecasting process and to the analysis of alternative pricing policies for energy.

Appendix A: Data

A.1 Introduction

The purpose of this data appendix is to provide further details of the construction of the data set used in the econometric estimation. As indicated in the text, the primary data source consists of establishment level observations from the Census of Manufacturing Establishments (CME) for NSW for the period 1977/78 to 1984/85. However, some extraneous information was needed to enable construction of the final data set.

The final data set consists of observations on the quantities x_i, marginal prices p_i and the observed values v_i for each of the inputs i (i = coal, oil, gas, electricity, labour, and capital), as well as the quantity, price and value of output for each establishment observed. In addition each observation is identified by the year and the 2-digit industry subdivision.

Since the precise data manipulations are very complicated and tedious to reproduce, only the essence of the manipulations are presented here.

A.2 Coal

The quantity of coal x_1, is taken to be a weighted sum of the quantities of its components, the weights being the gigajoules per unit of quantity. The components and the corresponding weights in gigajoules (GJ) per tonne are:

Black coal	30.0	in ASIC (294) (steelmaking)
	23.9	else
Brown coal	9.5	
Briquettes	22.3	
Coke	27.0	
Coke breeze	27.0	

These weights are based upon the Energy Authority of NSW publication Coal in New South Wales (EA86/37).

The values purchased of each component were summed to give v_1, and the average price in dollars per GJ was obtained as $p_1 = v_1/x_1$.

A.3 **Oil**

A similar procedure was used for oil. The components of oil and their weights (obtained from the NSW Department of Energy) are:

Diesel (industrial and marine)	45.5	GJ/tonne
Other petroleum oils	.0344	GJ/litre

Again the values of the components were summed to give v_2, and the average price in dollars per GJ was obtained as $p_2 = v_2/x_2$.

A.4 **Gas**

In the CME information is provided on the quantity and value of liquid petroleum gas (LPG) purchases and the value of mains gas purchases. However, no information is requested of establishments on the quantity of mains gas purchased. As a result extraneous information had to be used to obtain an estimate of the quantity of gas purchased and its price.

There are several features of the pricing of mains gas that are of particular concern here: (1) the price structure is different for the three major classes of gas customers:- non-contract, contract, and special contract customers, and (ii) the price structure differentiates between an energy charge and a demand charge. Further details of the pricing structure are available in the Energy Authority of NSW publication Gas in New South Wales (EA86/35). The procedures described below make extensive use of published schedules for industrial tariffs and for industrial contract tariffs for gas consumption.

The procedure used to obtain the quantity of gas used and its corresponding marginal price is as follows:

(a) For each establishment the value of gas purchases v_3 is available in the CME data base. This value was used along with the published gas price schedule for industrial non-contract customers to obtain an estimate of the quantity of gas that would have been purchased had that schedule applied, and the corresponding marginal price. The schedules used vary from year to year, and separate schedules were used for Newcastle and the Sydney regions. The Sydney price schedule was assumed to apply to the rest of the state also.

If this estimate of gas consumption exceeded 10,000 GJ then it was assumed, based upon AGL practice, that the customer would be classed as a contract customer. In this case the industrial contract price schedule was used to determine the quantity of gas purchased and the corresponding marginal price. Otherwise, the quantity and marginal price based upon the non-contract schedules was used.

(b) The industrial contract customer price schedules distinguish between an energy charge and a demand charge. The problem arises as to how to split the total gas bill between these two components so as to determine the quantity of gas purchased. This problem was resolved by assuming that the density function for the consumption of gas over the monthly billing period is uniform. Assuming 20 working days per month we obtain that the demand quantity is 1/20 times the energy quantity. On the basis of this assumption a single price schedule that takes account of both the demand and energy charges may be constructed. This resulting schedule was then used to determine the quantity and marginal price for industrial contract customers, given their observed total expenditure on gas.

(c) The special contract customers have individually negotiated contracts with the gas supplier Australian Gas Light (AGL). For each of these customers AGL provided information as to the average price paid for gas in each year. The average price paid was taken as p_3 for these customers since the marginal price is unknown (and would depend upon the nature of the special contract). The average price is generally lower than the smallest contract marginal price and since the special contract customers are very large it is unlikely that there would be a substantial difference between the marginal and average prices.

As a result of this procedure we have for each establishment the value of mains gas purchases, the quantity of mains gas purchased and its marginal price. Of course, division of the value by the quantity yields the average price.

For LPG information is available on both the value and quantity of purchases, so the price was obtained as value divided by quantity.

Gas was taken to be made up of two components, namely mains gas and LPG. The quantity of gas in GJ (x_1) was taken to be a weighted sum of these, the weight for LPG being 0.05 GJ/Kilogram. The marginal price index for gas p_3 was then computed as the marginal value of gas (mains gas was evaluated at its marginal price) divided by the quantity of gas x_3.

A.5 **Electricity**

As with gas the CME data base includes the value of electricity purchased by each enterprise but does not include the quantity purchased. Accordingly, it was necessary to make use of published price schedules for electricity together with some assumptions regarding the relationship between demand and energy components of electricity bills to obtain estimates of the quantity of electricity purchased and its marginal price.

The procedure used was as follows:

(a) The observed value of electricity consumption v_4 was compared with a critical value (depending upon the year of observation) to determine whether the establishment should be classed as a non-demand customer (less than the critical value) or as a demand customer (greater than). This strategy and the critical values were obtained by a NSW Department of Energy study of data for 1543 non-domestic electricity users (in the manufacturing sector) from the Prospect County Council (1984/85) and data on the top 400 electricity users in NSW (1983/84).

(b) For non-demand customers the value of electricity is used along with the non-demand tariff schedule applicable to that enterprise to obtain the implied quantity of electricity in kilowatt hours (kwh) x_4 and the marginal price p_4. The applicable schedule was determined by identifying the geographical location of the enterprise and using the schedule of that area's local supplier of electricity. Thus, use was made of schedules for the following County Councils: Illawarra, Prospect, Shortland and Sydney. In addition, use was made of a schedule constructed for rural councils.

(c) For demand customers the same procedure was followed, using the applicable demand tariff schedule. The additional problem here is that there are separate demand and energy charges for electricity. It was assumed that the demand share (proportion) s of the total electricity bill v is

$$s = \exp(a-b*v)/[1 + \exp(a-b*v)]$$

where

$$a = -0.2469 \quad , \quad b = I* 1.734 \text{ E-07}$$

and I is an index used to deflate electricity values. This formula is based upon a detailed statistical analysis of the two data sets referred to in part (a) above. These data sets contained information on the demand and energy components of electricity bills, allowing the estimation of the parameters a and b of the above equation.

This equation may be used to split the total electricity bill into its demand and energy components. The demand customer schedules are then used to obtain the quantity of electricity x_4 and the marginal price paid p_4.

The above procedure yields for each establishment the value of electricity, the quantity purchased and its marginal price. The latter two variables were converted into GJ equivalents, using the conversion factor of 0.0036 GJ/Kwh.

A.6 **Labour**

The quantity of labour x_5 was taken to be the "average employment for the period during which the establishment operated", a variable constructed by the ABS on the basis of detailed information provided in the census return. The value of labour or total labour cost v_5 was taken to be the sum of the wages bill for administrative employees and the wages bill for production employees. The wage rate was then computed as $p_5 = v_5/x_5$.

A.7 **Capital**

The cost of capital is v_6 obtained as a residual. It is taken to be the value of output (defined in section A.8 below) minus the value of labour minus the value of the four fuels. It thus represents the income accruing to capital.

Unfortunately, there is no direct information on the quantity of capital services or on the capital stock. Information is provided on investment, but this does not help get capital stocks. Accordingly, some extraneous data had to be used.

It was assumed that the rental price index of capital p_6 was the same for all establishments in a particular year but varied over time. It was defined as the price index for private plant and equipment investment (PIPE) multiplied by the user cost of capital (RIPE), both of these variables being obtained from the National Income Forecasting (NIF-105) model data base.

This index of the rental price of capital is then divided into the rental value of capital to obtain an estimate of the capital stock, which we assume is proportional to the capital services it provides. Thus we end up with the rental value of capital v_6, the rental price of capital p_6 and the quantity of capital x_6 for each establishment.

A.8 **Output**

The CME data base provides information on the value added by the establishment. The total value of purchases of all four fuels was added to the value added variable to obtain a measure of the value of output or production.

Unfortunately, the CME data base has no useful information on the price index or the quantity index of output. As a result extraneous information had to be used. In particular, use was made of the "Price Indices for Articles Produced by Manufacturing Industry" published and described in ABS catalogue 6412.0. Annual indices were provided by the ABS for each of the 12 ASIC 2-digit subdivisions used in this study. Use of this data assumes that all establishments in a particular subdivision have the same price index for output.

The quantity of output was then obtained as the value divided by the price index. Thus, for each enterprise we obtain the value, price and quantity of output.

Appendix B: Parameter estimates and system R-squared values

Table B.1 Parameter estimates for share equations (Model A)

Table B.1.1 Parameter Estimates : Fuel Pattern 1 (multiplied by 100)

	COAL	OIL	GAS	ELEC	LAB	CAP
INTERCEP	11.513	.281	4.046	-9.150	-58.043	151.353
LP_C	1.457	.113	.349	-.643	-1.607	.331
LP_O	.113	-1.523	.158	-1.035	1.284	1.003
LP_G	.349	.158	-2.096	-.090	.385	1.293
LP_E	-.643	-1.035	-.090	-.498	1.574	.690
LP_L	-1.607	1.284	.385	1.574	13.639	-15.274
LY	.392	-.424	-.205	-.013	-2.838	3.089
D23	.886	-.317	.735	-.847	2.934	-3.391
D25	-1.890	10.062	.288	3.416	-15.440	3.564
D26	.667	-.294	-.438	-.884	3.447	-2.498
D27	-.295	.952	1.358	1.671	-17.748	14.062
D28	3.564	2.221	1.080	2.418	-4.394	-4.890
D29	2.414	.338	.751	1.208	1.188	-5.900
D31	-1.115	-.359	.146	-.577	4.058	-2.153
D32	-2.052	.043	.123	-1.057	14.416	-11.473
D33	-1.349	-.533	-.221	-.555	15.069	-12.411
D34	-.949	.212	-.003	.562	.842	-.663
T	.200	.008	-.048	.384	-.123	-.421

Table B.1.2 Parameter Estimates : Fuel Pattern 2 (multiplied by 100)

	OIL	GAS	ELEC	LAB	CAP
INTERCEP	14.135	7.902	6.302	22.027	49.634
LP_O	-.967	-.162	-.458	-.120	1.707
LP_G	-.162	-1.877	-.584	.360	2.263
LP_E	-.458	-.584	-1.882	.754	2.170
LP_L	-.120	.360	.754	6.089	-7.083
LY	-.459	-.253	-.184	-3.076	3.972
D23	.443	.232	.993	1.621	-3.289
D24	-1.539	-.379	-1.130	21.844	-18.796
D25	-.547	-.500	-.227	6.337	-5.064
D26	-1.787	-.298	-.781	5.435	-2.569
D27	-.474	.273	-.465	-5.246	5.912
D28	.764	3.352	.711	-3.445	-1.381
D29	.421	.379	.990	2.415	-4.205
D31	-1.416	.186	-.722	6.251	-4.299
D32	-1.186	-.279	-.946	17.100	-14.688
D33	-1.678	-.216	-1.138	10.603	-7.570
D34	-1.167	-.121	-.159	7.649	-6.203
T	.002	-.044	.227	-.023	-.163

Table B.1.3 Parameter Estimates : Fuel Pattern 3
(multiplied by 100)

	COAL	GAS	ELEC	LAB	CAP
INTERCEP	-2.756	2.233	-22.236	51.708	71.050
LP_C	.348	-.048	-.530	1.126	-.896
LP_G	-.048	-2.759	-.227	.870	2.164
LP_E	-.530	-.227	-1.520	3.648	-1.370
LP_L	1.126	.870	3.648	1.292	-6.937
LY	-.477	-.152	-.481	-2.224	3.333
D23	2.958	-.730	-.690	14.685	-16.222
D25	-2.921	.492	-3.690	-3.107	9.227
D26	-.092	1.815	-.510	-5.128	3.914
D27	-.443	.605	-2.072	-1.462	3.372
D28	5.096	4.518	.104	1.018	-10.736
D29	2.769	.775	-1.209	4.421	-6.756
D31	-2.255	.451	-2.513	1.597	2.720
D32	-.566	.639	-2.154	33.469	-31.388
D33	-.690	-.243	-.753	9.762	-8.077
D34	.216	.715	.050	14.736	-15.717
T	.212	-.298	.339	.011	-.265

Table B.1.4 Parameter Estimates : Fuel Pattern 4
(multiplied by 100)

	COAL	OIL	ELEC	LAB	CAP
INTERCEP	-6.341	13.552	-11.105	-9.369	113.264
LP_C	.516	.506	-.899	.781	-.903
LP_O	.506	-1.568	-.538	.456	1.144
LP_E	-.899	-.538	-.008	.970	.476
LP_L	.781	.456	.970	8.988	-11.195
LY	.077	-.850	.470	-3.136	3.439
D23	-.637	1.411	-.485	.570	-.859
D24	-1.185	.881	-.043	22.213	-21.865
D25	-1.346	-.559	-.428	-4.602	6.936
D26	-1.442	-1.151	-1.794	19.846	-15.459
D27	4.929	.303	-1.637	16.701	-20.297
D28	8.045	1.660	1.095	-1.177	-9.623
D29	1.635	-1.836	-1.142	12.129	-10.786
D31	-1.729	-3.778	-.751	19.138	-12.881
D32	-2.172	-.508	-2.479	37.258	-32.099
D33	-1.445	-2.062	-1.353	8.776	-3.916
T	.255	.117	.365	-.629	-.107

Table B.1.5 Parameter Estimates : Fuel Pattern 5
(multiplied by 100)

	GAS	ELEC	LAB	CAP
INTERCEP	5.274	7.371	4.641	82.713
LP_G	-2.168	-.806	1.035	1.939
LP_E	-.806	-1.817	.635	1.988
LP_L	1.035	.635	8.972	-10.642
LY	-.444	-.194	-4.116	4.754
D23	-.263	.068	4.647	-4.452
D24	-.261	-1.434	16.096	-14.402
D25	-.909	-.553	3.807	-2.346
D26	-.865	-1.331	8.748	-6.551
D27	-.282	-1.041	-6.593	7.917
D28	4.025	.073	-4.690	.592
D29	.695	.206	1.792	-2.694
D31	-.350	-1.063	4.362	-2.949
D32	-.733	-1.530	7.440	-5.177
D33	-.818	-1.342	8.182	-6.022
D34	-.636	-.495	3.794	-2.663
T	-.073	.158	.180	-.266

Table B.1.6 Parameter Estimates : Fuel Pattern 6
(multiplied by 100)

	OIL	ELEC	LAB	CAP
INTERCEP	19.254	9.030	-1.034	72.750
LP_O	-1.202	-.486	-.743	2.431
LP_E	-.486	-1.030	-.119	1.635
LP_L	-.743	-.119	11.127	-10.265
LY	-.258	-.029	-5.038	5.325
D23	-1.534	.314	.547	.673
D24	-3.318	-1.836	17.665	-12.510
D25	-1.237	-.779	-.780	2.797
D26	-3.167	-1.529	8.490	-3.794
D27	-1.614	-1.084	-7.651	10.348
D28	1.528	-.680	-11.074	10.227
D29	.103	-.007	-2.937	2.841
D31	-1.960	-.857	3.587	-.770
D32	-2.382	-1.286	10.330	-6.662
D33	-2.959	-1.371	7.068	-2.737
D34	-1.638	-.400	1.670	.368
T	.080	.182	.325	-.587

Table B.1.7 Parameter Estimates : Fuel Pattern 7
(multiplied by 100)

	COAL	ELEC	LAB	CAP
INTERCEP	-11.898	1.636	97.957	12.305
LP_C	-.564	-.633	.563	.634
LP_E	-.633	-.757	.454	.937
LP_L	.563	.454	-.616	-.402
LY	.753	.019	-3.027	2.255
D23	-.359	-1.673	3.953	-1.920
D24	-1.337	-3.710	-4.275	9.322
D25	2.901	3.272	1.898	-8.071
D26	2.067	-.921	1.168	-2.315
D27	-2.724	-3.467	-9.105	15.295
D28	12.955	-.112	-2.701	-10.141
D29	5.153	-2.215	-1.605	-1.332
D31	1.939	-2.694	.987	-.232
D32	1.029	-2.087	8.735	-7.677
D33	1.026	-2.605	5.195	-3.616
D34	12.051	-1.352	-5.829	-4.871
T	.280	.367	-1.019	.372

Table B.1.8 Parameter Estimates : Fuel Pattern 8
(multiplied by 100)

	ELEC	LAB	CAP
INTERCEP	8.795	-50.290	141.495
LP_E	-.528	-.321	.848
LP_L	-.321	17.588	-17.267
LY	-.007	-6.655	6.662
D23	-2.589	7.419	-4.829
D24	-2.656	12.525	-9.869
D25	-2.259	3.226	-.967
D26	-2.457	3.770	-1.313
D27	-1.574	-8.119	9.693
D28	-2.065	-12.107	14.172
D29	-1.107	-4.207	5.314
D31	-2.369	2.666	-.297
D32	-2.439	5.897	-3.458
D33	-2.422	4.402	-1.980
D34	-1.440	2.526	-1.087
T	.094	.769	-.863

Table B.1.9 Parameter Estimates : Fuel Pattern 9
(multiplied by 100)

	OIL	LAB	CAP
INTERCEP	8.412	1.410	90.178
LP_O	.545	-.492	-.054
LP_L	-.492	13.972	-13.480
LY	-.117	-8.147	8.264
D23	-3.103	3.557	-.454
D24	-3.742	23.756	-20.013
D25	1.038	-20.151	19.114
D26	-2.666	12.881	-10.215
D27	4.792	-17.293	12.501
D28	3.398	-8.498	5.100
D29	-2.511	11.940	-9.428
D31	.263	1.969	-2.231
D32	-2.397	-9.299	11.695
D33	-2.403	7.042	-4.639
D34	-2.465	1.568	.897
T	.049	2.775	-2.825

Table B.2 Estimates of "non-price" parameters (Model A)

Subdivision	intercept g	output f	time h
1	5.00959558	.396008226	.707183905E-01
2	-9.60769905	1.50095652	.349142810E-01
3	-7.26417097	1.33288561	.589321624E-01
4	8.05548657	.106958546	.401368543E-01
5	-8.19683557	1.41983367	.493073334E-01
6	9.84976290	.158798834	.403272758E-01
7	-8.62535003	1.47749596	.106437775
8	-2.95533171	1.01005035	.103812079
9	6.21136520	.250285650	.240171164E-01
10	-3.39872008	.979074599	.767501488E-01
11	-9.81937362	1.52779991	.748831919E-01
12	-.667612278	.827916665	.399005984E-01

Table B.3 System R-squared values for share equations (Model A)

Fuel pattern	1	2	3	4	5	6	7	8	9
System R-squared	.27	.17	.45	.44	.21	.16	.33	.17	.59

Table B.4 System R-squared values for share equations (Model B)

	Industry subdivision											
Fuel pattern	21	23	24	25	26	27	28	29	31	32	33	34
1	.40	.47				.56	.56	.38	.49		.49	
2	.12	.32	.39	.19	.13	.10	.19	.19	.10	.12	.08	.16
3	.31	.95				.81	.85	.65			.78	.85
4	.20			.94		.94	.41	.63	.45	.75	.89	
5	.18	.21	.24	.12	.15	.20	.17	.22	.13	.13	.08	.21
6	.09	.18	.16	.10	.10	.07	.12	.24	.09	.07	.09	.13
7	.11	.86		.81	.99		.33	.24	.24	.98	.89	.60
8	.19	.07	.06	.18	.14	.22	.10	.11	.15	.12	.11	.14
9												

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Glossary

Cost function

An expression relating the minimum cost of production to the level of output produced and the prices of each of the inputs ~~to~~ of the production process. The function depends upon the state of the technology, which defines the input combinations that can produce given output levels.

Cross-price elasticity of demand

The percentage change in the demand for an input as a result of a 1 percent increase in the price of another input.

Econometric model

A formal relationship (usually expressed mathematically as an equation) between endogenous variables, explanatory variables and random disturbances. The relationship involves unknown constants (parameters) which are to be estimated using observed data.

Elasticity of demand with respect to own-price

The percentage change in the demand for an input as a result of a 1 percent increase in the price of that same input. This is sometimes called the own-price elasticity of demand.

Endogenous variable

A variable that is explained by the model.

Exogenous variable

A variable that is not explained by the model, but is taken as given.

Explanatory variable

A variable that is used to explain an endogenous variable.

Input demand functions

Expressions relating the quantity demanded of each input to the level of output produced and the prices of each of the inputs.

Output elasticity of demand

The percentage change in the demand for an input as a result of a 1 percent increase in the level of output produced.

Time rate of change in demand

The percentage change in the demand for an input due to the passage of 1 unit of time (a year).