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THE DEMAND FOR ENERGY IN DUTCH MANUFACTURING; A STUDY USING PANEL DATA OF INDIVIDUAL FIRMS, 1978-1986 *).

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ABSTRACT

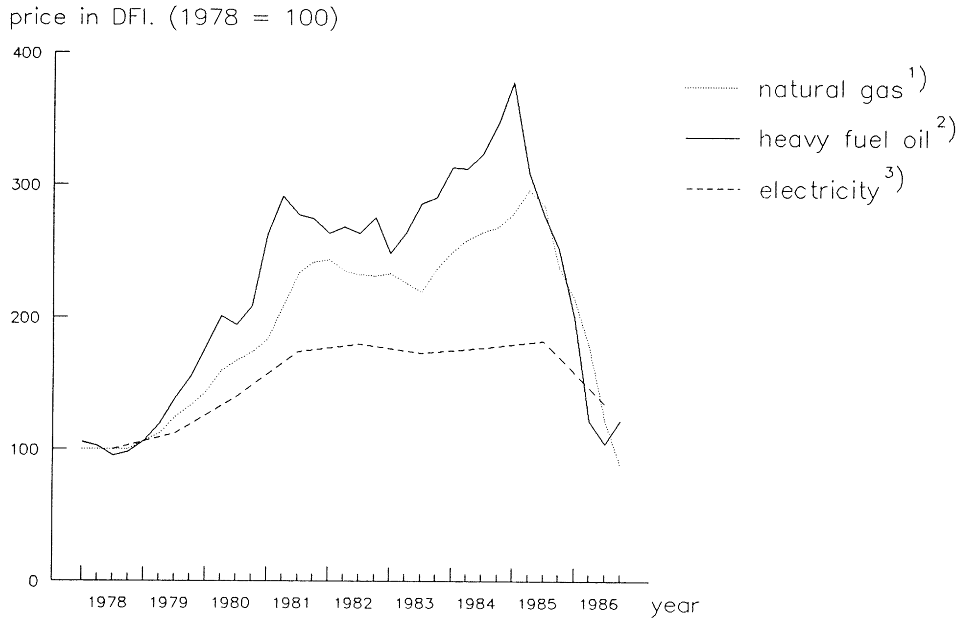
In this paper we analyse a rather unique data set, consisting of panel data pertaining to several thousands of Dutch manufacturing firms. We concentrate on the input of energy. As in most other industrialized countries the oil price shocks of the seventies have led to major rearrangements in the production processes in Dutch manufacturing. The openness of the Dutch economy exerts a substantial competitive pressure on the costs of production, necessitating the substitution of (expensive) energy consuming processes by less energy intensive ones. This adjustment process is investigated by means of a dynamic equation derived from the neoclassical theory of the firm. It relates the demand for energy to the level of output, the price of energy and the prices of other inputs. For total manufacturing a long term price elasticity of energy of -0.56 is estimated. For partitions of total manufacturing according to firm size, energy intensity and investment/output ratio, the partition according to firm size gives the largest differences between the estimated energy price elasticities.

1. *Introduction*

After the first oil price shock (1974-1975) energy prices remained at a significantly higher level than before. From this moment on energy costs could not be neglected any more. Therefore, the enormous increases in Dutch energy prices in the period 1979-1985 (see figure 1) were dramatic. The latter increases were not only caused by the second oil price shock (1979-1980), but also by the strong increase in the exchange rate: from 2 guilders per dollar in 1981 to almost 4 at the beginning of 1985. The basic question of this paper is how firms react to such an exceptional increase in the cost of one of their factors of production.

Manufacturing firms being relatively capital intensive, production processes are likely to be largely fixed, so that energy consumption patterns cannot be changed substantially in the short run. Obviously, there are some possibilities to reduce heating of work-rooms and factory-

Figure 1. Dutch energy prices, 1978 – 1986



1) firms using 1 million – 10 million m^3 per year (CBS, 1986)
2) manufacturing firms using >= 2 million kg per 3 months (CBS, 1986)
3) large consumers (CBS, 1978/1986c)

buildings, to insulate buildings, etc., but replacement of energy-intensive capital equipment by a less energy-intensive one is costly and takes time. At the macro-economic level input substitution may be observed when energy-intensive firms go bankrupt and get replaced by less energy-intensive ones, which are more adapted to the ruling relative input prices. However, at the micro-economic level it is an important question how much flexibility the already existing firms have in their use of energy over a period of two to five years. To which amount and how fast do firms reduce their demand for energy when prices increase? Do we find any differences in reaction as between types of economic activity? Do reaction patterns depend upon the energy intensity, the capital intensity and the size of the firm? To what extent is the speed of adjustment related to the amount of investment?

In order to get an answer to these questions we have estimated an equation for the share of energy costs in the total costs of production. In line with the neoclassical theory of the firm we assume that firms choose a bundle of inputs such that the total costs of producing a given level of output are minimal. We then find that the demand for inputs, including the input of energy, depends on the level of output, the substitution possibilities among inputs allowed by the production technology, and the relative prices of all inputs (Berndt and Wood, 1975). The energy cost share equation we actually employ is derived from a translog cost function associated with a production technology with four input factors: capital, labor, energy and material inputs. Contrary to many other studies (for example Berndt and Wood, 1975, Fuss, 1977, Magnus, 1979, Pindyck, 1979) we estimate this cost share equation with panel data of individual firms. The panel structure of the data allows us to circumvent the lack of data on prices of inputs other than energy by introducing suitable fixed effects.

The structure of the paper is as follows. In section 2 we describe our data, concentrating on the construction of the panel, the energy prices and the energy input levels. In section 3 we derive the energy cost share equation and present our estimation results. Section 4, finally, summarizes the most important findings of our study.

2. *The data*

The Netherlands Central Bureau of Statistics collects data on individual firms in manufacturing. In a yearly inquiry firms are asked for detailed information on inputs and outputs. This information contains, amongst others, the number of employees, the total wage bill, sales, material inputs and the values and quantities of inputs of electricity and natural gas. All firms with 10 or more employees are observed; smaller firms are excluded. For about seventy industry groups aggregated data are published annually in Production Statistics (CBS, 1978/1986a).

Over the period 1978-1986 the number of firms is approximately 8500 per year. Pooling the annual data, we constructed our panel by selecting those firms satisfying the following selection rules:

- a firm is present each year during the period 1978-1986;
- the value and volume of the inputs of natural gas and electricity are not missing. The implicit prices (unit values) do not exceed the energy prices charged to households by more than 25% in any year;
- investment data are available for the whole period 1978-1986. These data are obtained from a yearly investment inquiry (CBS, 1978/1986b) covering the same statistical units as the Production Statistics. However, with respect to the investment data there is a non-response of about 15%;
- for each year over the period 1979-1986 the price as well as the cost share of energy is between 0.2 and 5 times the price and the cost share of energy in 1978.

The above requirements lead to a time-series of a cross-section of 1643 firms. The representativity of this panel with respect to total manufacturing is discussed in the appendix.

In the remainder of this section we consider the main variables used in this study: energy prices, the energy cost share, and the level of real output. Averages are given for 15 manufacturing industries. In subsection 2.1 we concentrate on the prices of electricity and natural gas. In subsection 2.2 we compare the development of the energy cost share with the development of real output and an energy price index.

2.1 *Prices of electricity and natural gas*

In The Netherlands the price a firm has to pay for electricity or natural gas generally depends on the quantity the firm has bought. Prices and quantities can be agreed upon in special contracts between a firm and its supplier of energy. Generally, prices decrease with the quantity demanded, so that *ex ante* prices paid by firms are equal to or less than prices paid by households. However, *ex post* it is possible that the price a firm pays for its input of electricity is higher than the price paid by households. This is caused by contracts in which a minimum quantity is agreed upon. If a firm stays below this minimum it has to pay a penalty.

The average prices of electricity and natural gas for each industry are presented in table 2.1. We see that, as expected, industries with a high energy use (SBI 26, 29/30, 32 and 33) have in general a lower average price level for both electricity and natural gas.

For electricity we can distinguish three sub-periods:

- during the period 1978-1982 the electricity price increases by about 60 per cent;
- during the period 1982-1985 the electricity price stablilizes at the level reached in 1982;
- in 1986 the electricity price decreases by about 15 per cent.

For natural gas we can distinguish the same three sub-periods:

- during the period 1978-1982 the natural gas price increases by more than 100 per cent;
- during the period 1982-1985 the natural gas price continues to increase, but at a slower rate (about 15 per cent in total);
- in 1986 the natural gas price level falls back to the price level of 1982 for most industries.

In 1986 most industries show a much higher standard deviation for the natural gas price than in all other years. This originates from exceptional price differences as between small and large consumers in 1986.

Table 2.1. Price of electricity and natural gas[a] by industry; firm averages

Industry[b]	Number of firms	Type of energy	Year								
			1978	1979	1980	1981	1982	1983	1984	1985	1986
			guilders (standard deviation)								
Manufacture of Food, Beverages and Tobacco (SBI 20/21)	323	Electricity	12.5 (2.4)	13.6 (2.6)	16.3 (2.9)	19.3 (2.8)	20.9 (3.1)	20.8 (3.5)	21.0 (3.7)	21.3 (3.8)	17.8 (3.9)
		Natural gas	20.4 (3.0)	22.9 (2.6)	28.5 (3.0)	38.8 (3.7)	44.9 (2.5)	46.9 (4.0)	50.5 (3.4)	52.3 (3.2)	43.5 (9.4)
Manufacture of Textiles (SBI 22)	68	Electricity	12.5 (2.7)	13.7 (3.3)	16.2 (3.0)	19.0 (2.9)	20.1 (3.0)	20.4 (3.7)	20.6 (4.0)	20.6 (3.9)	17.7 (4.5)
		Natural gas	20.2 (3.6)	23.7 (3.1)	28.6 (3.5)	38.4 (3.3)	44.8 (3.4)	46.3 (3.5)	50.1 (3.7)	52.4 (4.4)	45.0 (10.4)
Manufacture of Wearing Apparel (SBI 23)	26	Electricity	14.9 (3.3)	15.3 (2.9)	18.4 (3.4)	22.3 (3.6)	21.8 (2.2)	22.9 (2.7)	24.9 (1.6)	25.0 (2.6)	21.5 (2.3)
		Natural gas	22.3 (3.6)	23.3 (4.5)	26.4 (4.9)	34.6 (6.9)	43.7 (3.0)	47.0 (2.7)	51.2 (2.1)	53.0 (4.5)	52.2 (4.8)
Manufacture of Leather Products (SBI 24)	16	Electricity	13.8 (2.2)	14.2 (1.9)	17.1 (2.5)	19.9 (2.5)	21.7 (2.6)	22.6 (3.7)	24.4 (3.6)	23.5 (4.3)	19.2 (3.4)
		Natural gas	21.0 (2.1)	23.4 (2.6)	28.5 (3.2)	38.4 (3.5)	43.3 (3.9)	46.1 (3.9)	50.3 (2.6)	53.0 (4.2)	50.1 (7.2)
Manufacture of Wood and Wood Products (SBI 25)	80	Electricity	15.5 (2.9)	17.5 (2.9)	19.5 (2.7)	22.2 (3.2)	23.8 (2.9)	23.2 (2.8)	23.5 (2.8)	24.1 (3.2)	20.3 (2.6)
		Natural gas	21.5 (3.5)	24.3 (2.7)	30.1 (2.4)	38.5 (4.4)	45.1 (4.4)	49.0 (3.4)	52.4 (3.4)	54.1 (3.5)	52.5 (4.6)
Manufacture of Paper and Paper Products (SBI 26)	74	Electricity	12.5 (3.2)	13.7 (3.6)	16.5 (3.6)	19.3 (3.6)	20.0 (3.5)	19.6 (3.8)	20.5 (4.8)	20.9 (4.8)	16.4 (4.3)
		Natural gas	18.7 (3.1)	22.0 (3.3)	28.4 (2.8)	38.3 (3.7)	45.0 (2.2)	45.7 (6.0)	50.1 (4.0)	53.1 (3.7)	42.0 (11.3)
Printing and Publishing (SBI 27)	216	Electricity	14.8 (2.7)	15.9 (2.6)	18.8 (2.7)	22.4 (2.9)	24.3 (3.0)	24.4 (3.0)	25.8 (3.0)	25.8 (3.1)	20.6 (3.4)
		Natural gas	20.9 (2.7)	24.0 (2.4)	29.7 (2.4)	37.3 (4.1)	43.2 (3.6)	48.8 (3.5)	52.0 (3.3)	54.7 (3.2)	49.8 (6.1)
Manufacture of Chemicals and Chemical Products (SBI 29/30)	90	Electricity	12.1 (3.5)	12.5 (2.9)	15.4 (3.5)	18.8 (3.9)	19.9 (3.9)	19.2 (4.4)	19.3 (5.1)	19.4 (5.2)	16.2 (4.6)
		Natural gas	19.2 (3.1)	22.0 (2.9)	28.2 (3.2)	37.4 (5.0)	44.2 (3.5)	54.4 (5.0)	48.8 (4.9)	51.7 (5.3)	40.9 (12.2)
Manufacture of Plastic and Rubber Products (SBI 31)	55	Electricity	12.1 (3.2)	13.0 (2.8)	15.0 (2.6)	18.7 (3.5)	20.3 (3.4)	18.8 (3.9)	19.2 (4.0)	19.8 (4.5)	16.3 (4.4)
		Natural gas	22.2 (3.1)	24.0 (2.1)	28.5 (2.8)	39.4 (2.6)	44.8 (3.3)	48.3 (4.6)	51.2 (3.4)	53.0 (4.0)	46.7 (10.2)
Manufacture of Building Materials, Earthenware, Glass (SBI 32)	104	Electricity	11.8 (2.8)	13.0 (2.9)	16.1 (3.3)	19.6 (3.9)	20.5 (4.2)	20.2 (4.8)	20.5 (5.0)	20.6 (4.9)	16.5 (4.1)
		Natural gas	18.4 (2.7)	21.3 (2.9)	28.1 (3.3)	38.0 (3.9)	44.2 (3.0)	45.3 (3.7)	49.2 (3.4)	51.7 (3.1)	37.9 (10.3)
Manufacture of Basic Metal Products (SBI 33)	25	Electricity	10.3 (3.6)	11.2 (3.6)	13.3 (4.0)	16.6 (5.0)	17.1 (5.7)	16.5 (5.7)	16.5 (6.1)	16.8 (6.0)	14.0 (4.7)
		Natural gas	18.4 (4.5)	20.9 (4.1)	26.8 (5.3)	36.9 (7.3)	41.9 (7.5)	43.1 (8.1)	47.1 (8.3)	49.6 (9.1)	36.7 (11.7)
Manufacture of Fabricated Metal Products (SBI 34)	241	Electricity	14.8 (3.0)	15.8 (2.6)	17.7 (2.4)	22.0 (3.0)	22.8 (3.2)	22.3 (3.3)	22.6 (3.5)	22.8 (3.3)	20.1 (3.5)
		Natural gas	21.4 (2.9)	23.6 (2.8)	29.4 (2.4)	39.4 (2.6)	45.8 (3.0)	48.5 (3.2)	52.3 (2.8)	53.7 (3.3)	49.4 (7.2)
Manufacture of Machinery (SBI 35)	216	Electricity	15.3 (2.4)	16.7 (2.6)	18.5 (2.9)	21.9 (3.1)	23.6 (3.1)	23.0 (3.2)	23.5 (3.2)	23.7 (3.2)	20.9 (3.4)
		Natural gas	22.1 (2.6)	24.4 (2.7)	29.9 (2.1)	39.6 (2.7)	46.0 (2.7)	48.4 (2.8)	51.9 (3.3)	54.1 (3.4)	52.7 (4.6)

Table 2.1. Price of electricity and gas[a] by industry; firm averages (continued)

Industry[b]	Number of firms	Type of energy	1978	1979	1980	1981	1982	1983	1984	1985	1986
			guilders (standard deviation)								
Manufacture of Electrical Products (SBI 36)	41	Electricity	14.2 (3.0)	15.1 (3.2)	17.0 (3.2)	21.4 (3.5)	21.8 (3.5)	21.5 (3.9)	21.9 (4.3)	21.9 (4.3)	20.2 (4.1)
		Natural gas	21.1 (3.3)	24.2 (3.4)	29.5 (2.5)	40.1 (2.6)	46.0 (3.9)	48.3 (2.4)	51.5 (3.2)	53.5 (3.8)	50.4 (7.6)
Manufacture of Transport Equipment (SBI 37)	68	Electricity	14.9 (3.2)	16.2 (2.9)	18.6 (3.0)	22.2 (3.6)	23.0 (3.1)	23.1 (3.3)	23.9 (3.6)	23.4 (3.2)	20.2 (3.1)
		Natural gas	21.5 (2.5)	23.7 (2.7)	30.0 (2.3)	39.3 (2.7)	45.6 (2.5)	48.1 (2.6)	51.7 (3.0)	53.1 (3.4)	48.4 (6.7)
Total (SBI 20/37)	1643	Electricity	13.7 (3.1)	14.8 (3.2)	17.3 (3.2)	20.7 (3.5)	22.0 (3.7)	21.8 (3.9)	22.3 (4.3)	22.4 (4.3)	18.9 (4.1)
		Natural gas	20.7 (3.2)	23.3 (2.9)	29.0 (2.9)	38.6 (3.8)	44.9 (3.3)	47.5 (4.0)	51.0 (3.7)	53.2 (3.8)	46.9 (9.4)

[a] Price of electricity in guilders per 100 kWh, price of natural gas in guilders per 100 m^3
[b] Following the Dutch Standard Industrial Classification (SBI) of 1974

2.2 *The energy cost share*

For 15 manufacturing industries the development of the cost share of energy, the development of real output and an index of the price of energy are shown in table 2.2. The cost share of energy is defined as energy costs divided by total costs. However, total costs are not available, so that we have taken total nominal output instead of total costs as the denominator when computing cost shares.

Table 2.2 shows that over the period 1978-1985 for all industries the increase of the cost share of energy is much lower than the increase of the energy price index.[1] In one way or another firms can save energy costs to a rather high amount. For total manufacturing we measure an 80 percent increase of the energy price over 8 years, while the increase of the cost share only amounts to 25 percent.

Table 2.2 shows that expanding industries, characterized by large increases in real output, have more possibilities to save energy: their

[1] The price index of energy is a Divisia index of the price index of electricity and the price index of natural gas. The prices of the remaining energy types are assumed to have the same development as the price of natural gas. The share of electricity and natural gas in total energy costs is 90.4 per cent in 1978 and 94.1 per cent in 1986 (averages per firm).

cost share of energy increases less rapidly than the cost share of industries with small increases in real output. This can be observed with SBI 26 (*paper and paper products*), SBI 29/30 (*chemicals and chemical products*), SBI 31 (*plastic and rubber products*), and SBI 36 (*electrical products*), being the four industries with the highest growth rates.

Two out of these four industries (SBI 26 and SBI 29/30) also belong to the group of four industries with the highest energy cost shares. The other two in this group are SBI 32 (*building materials, earthenware and glass*) and SBI 33 (*basic metal products*). For these two industries there is no significant growth in real output over the period 1978-1986, though.

Table 2.2 shows that at the end of the period under consideration energy prices fall dramatically (see also figure 1). It is remarkable that for the energy-intensive SBI 33 (*basic metal products*) the cost share of energy is higher in 1986 than in 1985, despite a more than average decrease in the energy price. This is due to a simultaneous decrease of the output price by almost the same amount as the energy price.

Table 2.2. Development of cost share[a] and price of energy[b] and real output[c] by industry; firm averages

Industry		Value[d] in 1978	1979	1980	1981	1982	1983	1984	1985	1986
			Indices 1978=100 (standard deviation)							
Manufacture of Food, Beverages and Tobacco (SBI 20/21)	Cost share of energy	0.018	113 (25)	133 (34)	154 (40)	161 (46)	159 (50)	161 (53)	167 (59)	138 (54)
	Real output	56,317	104 (15)	109 (31)	111 (37)	114 (40)	116 (45)	120 (50)	126 (58)	130 (64)
	Price of energy		112 (16)	138 (21)	178 (29)	200 (31)	204 (33)	215 (34)	220 (37)	181 (39)
Manufacture of Textiles (SBI 22)	Cost share of energy	0.023	107 (24)	119 (33)	142 (42)	146 (53)	143 (49)	142 (57)	145 (64)	119 (65)
	Real output	19,712	108 (25)	115 (42)	113 (45)	116 (56)	115 (60)	120 (72)	127 (86)	130 (97)
	Price of energy		115 (13)	139 (14)	177 (24)	198 (25)	203 (25)	214 (29)	219 (32)	184 (34)
Manufacture of Wearing Apparel (SBI 23)	Cost share of energy	0.007	109 (28)	123 (35)	150 (54)	166 (59)	165 (61)	168 (61)	162 (65)	130 (50)
	Real output	8,577	107 (18)	106 (26)	99 (23)	99 (30)	98 (35)	98 (35)	110 (63)	115 (64)
	Price of energy		105 (8)	123 (18)	157 (26)	179 (37)	189 (33)	207 (36)	210 (38)	193 (36)
Manufacture of Leather Products (SBI 24)	Cost share of energy	0.009	108 (29)	108 (30)	139 (35)	151 (36)	138 (45)	151 (55)	145 (54)	131 (54)
	Real output	5,949	107 (19)	109 (21)	99 (22)	104 (25)	113 (38)	108 (50)	119 (70)	119 (78)
	Price of energy		109 (11)	133 (18)	167 (20)	184 (24)	194 (24)	212 (27)	214 (28)	191 (29)
Manufacture of Wood and Wood Products (SBI 25)	Cost share of energy	0.012	122 (36)	129 (50)	154 (67)	162 (61)	153 (64)	153 (70)	163 (77)	138 (65)
	Real output	5,935	99 (15)	103 (23)	97 (25)	92 (29)	92 (27)	95 (33)	98 (34)	102 (40)
	Price of energy		116 (16)	137 (22)	165 (32)	185 (35)	191 (37)	198 (38)	204 (40)	183 (36)
Manufacture of Paper and Paper Products (SBI 26)	Cost share of energy	0.031	106 (28)	115 (33)	132 (28)	135 (30)	132 (37)	128 (36)	129 (37)	104 (41)
	Real output	23,832	109 (12)	111 (15)	113 (17)	114 (20)	118 (25)	128 (33)	134 (36)	136 (37)
	Price of energy		114 (13)	143 (18)	180 (21)	198 (26)	197 (26)	214 (36)	221 (39)	167 (34)
Printing and Publishing (SBI 27)	Cost share of energy	0.009	111 (30)	125 (39)	152 (50)	162 (56)	159 (59)	157 (50)	157 (48)	134 (46)
	Real output	13,367	106 (12)	108 (17)	102 (23)	99 (23)	95 (27)	98 (30)	103 (38)	114 (66)
	Price of energy		112 (16)	135 (19)	164 (23)	183 (25)	193 (29)	204 (31)	209 (33)	176 (31)
Manufacture of Chemicals and Chemical Products (SBI 29/30)	Cost share of energy	0.043	105 (22)	117 (31)	135 (37)	140 (42)	133 (53)	130 (51)	158[e] (81)	120[e] (59)
	Real output	101,301	100 (19)	102 (24)	105 (26)	109 (33)	114 (39)	122 (42)	130 (47)	132 (52)
	Price of energy		112 (15)	142 (21)	183 (30)	209 (37)	208 (37)	218 (41)	228 (45)	182 (51)
Manufacture of Plastic and Rubber Products (SBI 31)	Cost share of energy	0.024	107 (16)	117 (25)	135 (33)	138 (35)	128 (34)	126 (37)	131 (43)	108 (44)
	Real output	18,241	105 (16)	103 (18)	109 (28)	111 (28)	119 (36)	123 (39)	129 (44)	137 (53)
	Price of energy		109 (18)	130 (24)	170 (34)	188 (40)	182 (39)	188 (40)	194 (40)	159 (32)

Table 2.2. Development of cost share[a] and price of energy[b] and real output[c] by industry; firm averages (continued)

Industry		Value[d] in 1978	1979	1980	1981	1982	1983	1984	1985	1986
			Indices 1978=100 (standard deviation)							
Manufacture of Building materials, Earthenware and Glass (SBI 32)	Cost share of energy	0.087	111 (19)	128 (29)	159 (40)	167 (56)	160 (52)	164 (50)	166 (47)	113 (37)
	Real output	19,239	97 (14)	96 (19)	87 (24)	80 (26)	83 (28)	89 (31)	92 (32)	96 (34)
	Price of energy		115 (13)	150 (23)	198 (31)	224 (35)	226 (35)	241 (37)	251 (40)	183 (42)
Manufacture of Basic Metal Products (SBI 33)	Cost share of energy	0.039	102 (24)	111 (28)	142 (44)	144 (40)	140 (41)	132 (39)	134 (34)	135 (67)
	Real output	221,620	104 (19)	111 (22)	110 (24)	102 (24)	99 (22)	103 (27)	110 (25)	104 (38)
	Price of energy		114 (17)	142 (22)	181 (31)	193 (29)	194 (29)	200 (36)	208 (36)	164 (27)
Manufacture of Fabricated Metal Products (SBI 34)	Cost share of energy	0.019	111 (31)	118 (38)	143 (48)	145 (51)	143 (50)	140 (53)	142 (54)	119 (53)
	Real output	13,032	105 (16)	111 (23)	106 (27)	106 (33)	102 (33)	114 (44)	121 (51)	128 (61)
	Price of energy		110 (13)	132 (17)	171 (22)	188 (25)	192 (27)	202 (29)	206 (29)	185 (31)
Manufacture of Machinery (SBI 35)	Cost share of energy	0.011	110 (24)	113 (29)	135 (43)	137 (46)	133 (40)	134 (44)	131 (47)	116 (48)
	Real output	16,426	104 (17)	110 (24)	108 (34)	109 (46)	107 (38)	111 (42)	123 (54)	128 (58)
	Price of energy		110 (11)	130 (14)	163 (19)	182 (22)	184 (23)	193 (25)	197 (26)	183 (27)
Manufacture of Electrical Products (SBI 36)	Cost share of energy	0.010	108 (23)	111 (24)	139 (37)	140 (46)	135 (43)	135 (48)	139 (63)	119 (53)
	Real output	33,374	109 (24)	116 (35)	110 (38)	118 (60)	120 (65)	128 (80)	144 (100)	151 (121)
	Price of energy		113 (24)	131 (26)	172 (35)	184 (37)	186 (37)	193 (39)	197 (39)	182 (39)
Manufacture of Transport Equipment (SBI 37)	Cost share of energy	0.012	111 (27)	122 (45)	137 (50)	140 (53)	140 (49)	149 (56)	151 (56)	130 (60)
	Real output	47,325	108 (33)	117 (62)	115 (42)	117 (61)	105 (52)	104 (41)	113 (69)	113 (66)
	Price of energy		111 (24)	134 (23)	169 (32)	185 (35)	190 (37)	201 (41)	202 (40)	178 (35)
Total (SBI 20/37)	Cost share of energy	0.022	111 (27)	122 (36)	145 (45)	151 (50)	147 (51)	147 (53)	151 (58)	125 (53)
	Real output	32,813	104 (17)	108 (28)	106 (31)	106 (39)	106 (40)	111 (45)	118 (55)	123 (63)
	Price of energy		112 (15)	136 (20)	173 (28)	193 (32)	197 (33)	207 (35)	213 (38)	180 (36)

a Energy costs divided by total nominal output
b Cf. footnote 1
c Nominal output deflated by a three digit (70 industry) output price index.
d Real output in thousands Dutch guilders.
e Including the use of energy as raw material.

3. *The demand for energy*

In this section we first derive the energy cost share equation to be estimated. Then we present and discuss our estimation results both by type of industry and by some other partitionings of the available data set.

3.1 *The energy cost share equation*

In line with the standard neoclassical theory of the firm we assume there exists a regular production function

$$Q = A\ f(K,L,E,M), \tag{1}$$

representing the underlying technology of a firm, where

Q: real output,
K: capital input,
L: labor input,
E: energy input,
M: (raw) materials input,
A: firm specific (efficiency) factor.

We assume that at the firm level factor prices and output are exogenously determined. Under this assumption, the theory of duality between cost functions and production functions (see for example Chambers, 1988, ch. 2) implies that (1) can be uniquely represented by a cost function

$$C = \min_{K,L,E,M} \{p_K K + p_L L + p_E E + p_M M:\ f(K,L,E,M) = Q/A\} \tag{2}$$

where

C : total cost of production,
p_i : price of input i, i = K, L, E, M.

The translog cost function is obtained as the logarithmic second-order

Taylor expansion of (2),

$$\log C = \alpha_0 + \alpha_Q \log(Q/A) + \sum_i \alpha_i \log(p_i) + \tfrac{1}{2}\gamma[\log(Q/A)]^2 +$$

$$\log(Q/A)\Big\{\sum_i \gamma_{iQ} \log(p_i)\Big\} + \tfrac{1}{2}\sum_i\sum_j \gamma_{ij} \log(p_i)\log(p_j), \qquad (3)$$

where

$i,j = K,\ L,\ E,\ M.$

Shephard's lemma implies that the cost-minimizing quantity demanded of the i^{th} input, x_i, equals $\partial C/\partial p_i$, so that we can write

$$V_i = \frac{p_i x_i}{C} = \frac{p_i}{C}\,\frac{\partial C}{\partial p_i} = \frac{\partial \log(C)}{\partial \log(p_i)}, \qquad (4)$$

where

V_i: cost share of the i^{th} input.

Combining (3) and (4) we obtain

$$V_i = \frac{\partial \log(C)}{\partial \log(p_i)} = \alpha_i + \gamma_{iQ} \log(Q/A) + \sum_j \gamma_{ij} \log(p_j). \qquad (5)$$

Only the energy cost-share equation of the system will be estimated. Furthermore, all prices of inputs other than energy will not be included explicitly. Therefore, we shall not discuss the restrictions on the parameters of (5) here. For these restrictions we refer to Christensen et al. (1973).

Adding firm and time indices for our panel, and restricting ourselves to the energy cost share equation we can write equation (5) as

$$(V_E)_{rt} = \alpha_E + \gamma_{EQ} \log(Q_{rt}/A_r) + \sum_j \gamma_{Ej} \log(p_j)_{rt}, \qquad (6)$$

where

r: firm index, $r = 1,\ldots,R$,
t: time index, $t = 1,\ldots,T$.

At the firm level we have no data for $(p_K)_{rt}$ and $(p_M)_{rt}$. For labor we have the number of employees as well as labor costs. So it is possible to approximate $(p_L)_{rt}$ by average labor costs per employee. Such a 'unit value' construct is strongly influenced by increases or decreases in the quality of labor and changes in the quantity of part-time labor. For this reason we also consider $(p_L)_{rt}$ to be missing. For the missing input prices jointly, we introduce a time-specific constant per industry

$$\beta_{st} = \gamma_{EK}\log(p_K)_{rt} + \gamma_{EL}\log(p_L)_{rt} + \gamma_{EM}\log(p_M)_{rt}, \qquad (7)$$

where

$s = s(r)$: index of the industry s to which firm r belongs.

The justification for this equation is that the classification in industries is based on the type of economic activity, so that the production processes of firms within an industry are relatively homogenous. Prices of materials and prices of investment goods (one of the determinants of the price of capital) may therefore be similar for firms within the same industry. The rate of interest and the corporate income tax rate (other determinants of the price of capital) do not differ much between individual firms. Furthermore, the wage rate is determined in contracts that are often industry-wide. So, prices of labor and capital may also be similar for firms within the same industry. Substitution of (7) in (6) gives

$$(V_E)_{rt} = \alpha_r + \beta_{st} + \gamma_{EQ}\log(Q_{rt}) + \gamma_{EE}\log(p_E)_{rt}, \qquad (8)$$

where

$$\alpha_r = \alpha_E - \gamma_{EQ}\log(A_r).$$

Equation (8) is a static equation. However, in general there may be a substantial delay in the reaction of firms to changes in prices of inputs such as energy. As mentioned earlier, in the short run there may not be much possibilities to reduce energy consumption. Therefore, it is necessary to replace (8) by a dynamic cost share equation once it comes to the empirical analysis. Since the development in energy prices is the key factor in explaining changes in energy shares, we introduce dynamics by adding lagged energy prices.

For notational purposes we introduce a generalized difference operator Δ which, for a general variable y_{rt} is defined as follows:

$$\Delta(y_{rt}) \equiv y_{rt} - y_{r.} - y^s_{.t} + y^s_{..},$$

where

$$y_{r.} \equiv (1/T) \sum_{t=1}^{T} y_{rt} \quad \text{(average over time for firm r)},$$

$$y^s_{.t} \equiv (1/R_s) \sum_{r \in V_s} y_{rt} \quad \text{(average over firms in industry s)},$$

$$y^s_{..} \equiv (1/T)\ (1/R_s) \sum_{t=1}^{T} \sum_{r \in V_s} y_{rt} \quad \text{(overall average)},$$

R_s : number of firms in industry s,
V_s : set of numbers of firms in industry s,

Applying Δ to (8) we can sweep out α_r and β_{st}; the resulting equation can be estimated with Ordinary Least Squares (OLS) on the transformed variables. The proof is straightforward; the obtained estimator is the so-called covariance estimator (Hsiao, 1986, p. 53). With lagged energy prices included the equation obtained reads as

$$\Delta(V_E)_{rt} = \gamma_{EQ}\Delta\log(Q_{rt}) + \gamma_{EE}\Delta\log(p_E)_{rt} + \gamma_{EE,-1}\Delta\log(p_E)_{rt-1} + \gamma_{EE,-2}\Delta\log(p_E)_{rt-2} + \gamma_{EE,-3}\Delta\log(p_E)_{rt-3} \qquad (9)$$

3.2 *Estimation results*

After adding a disturbance term, we estimate equation (9) for each industry as well as for total manufacturing.[2] The estimation results are presented in table 3.1. We have also calculated the elasticity of energy demand with respect to the level of output, η_Q, and the own price elasticity of energy demand η_p.[3] We note that η_Q is not the usual scale elasticity of energy since it does not represent cross-sectional variation as such. In equation (9) log Q_{rt} is taken as a deviation of its mean over time. Therefore, η_Q represents scale effects over time. The price elasticity of energy, η_p, is the long run price elasticity.[4]

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[2] As mentioned in footnote c in table 2.2, we use output price index numbers at a 3^{rd}-digit SBI level to deflate nominal output. Furthermore, we use total output instead of total costs to obtain the cost-share.

[3]

$$\eta_Q = \frac{\partial \log(E)}{\partial \log(Q)} = \frac{\gamma_{EQ}}{\bar{v}_E} + 1; \quad \eta_p = \frac{\partial \log(E)}{\partial \log(p)} = \frac{\gamma_{EE} + \gamma_{EE,-1} + \gamma_{EE,-2} + \gamma_{EE,-3}}{\bar{v}_E} - 1 + \bar{v}_E \; ; \; \bar{v}_E = (1/T) \sum_{t=1}^{T} (v_E)_t$$

[4] The energy price of a firm is a weighted average of the prices of electricity and natural gas. For natural gas average prices are not equal to marginal prices since these prices follow a declining rate schedule (quantity x_1 for price x_1, quantity x_2 for price $x_2 < x_1$ after consuming quantity x_1, etc.). Therefore we have re-estimated equation (9) with marginal prices instead of average prices. For total manufacturing the estimated scale elasticity obtains as 0.61 and the price elasticity as -0.60.

Table 3.1. Parameter estimates for the energy share equation (9) by industry (standard deviations between parentheses)

Industry	γ_{EQ}	γ_{EE}	$\gamma_{EE,-1}$	$\gamma_{EE,-2}$	$\gamma_{EE,-3}$	R^2 [a]	η_Q	η_P
Manufacture of Food, Beverages and Tobacco (SBI 20/21)	-0.0085 (0.0009)	0.0148 (0.0018)	-0.0033 (0.0023)	-0.0042 (0.0022)	-0.0041 (0.0019)	0.97	0.69 (0.03)	-0.85 (0.13)
Manufacture of Textile Products (SBI 22)	-0.0113 (0.0019)	0.0221 (0.0036)	0.0030 (0.0056)	-0.0003 (0.0051)	0.0037 (0.0046)	0.96	0.64 (0.06)	-0.05 (0.26)
Manufacture of Wearing Apparel (SBI 23)	-0.0064 (0.0009)	0.0036 (0.0023)	0.0000 (0.0020)	-0.0025 (0.0018)	0.0051 (0.0016)	0.92	0.43 (0.08)	-0.43 (0.27)
Manufacture of Leather Products (SBI 24)	-0.0090 (0.0009)	0.0061 (0.0023)	0.0021 (0.0020)	-0.0013 (0.0018)	-0.0052 (0.0016)	0.94	0.20 (0.11)	-0.83 (0.52)
Manufacture of Wood and Wood Products (SBI 25)	-0.0118 (0.0010)	0.0023 (0.0023)	-0.0039 (0.0024)	-0.0016 (0.0022)	-0.0040 (0.0018)	0.88	0.32 (0.06)	-1.40 (0.22)
Manufacture of Paper and Paper Products (SBI 26)	-0.0120 (0.0037)	0.0304 (0.0049)	-0.0117 (0.0060)	-0.0042 (0.0058)	-0.0126 (0.0060)	0.97	0.68 (0.10)	-0.91 (0.26)
Printing and Publishing (SBI 27)	-0.0071 (0.0005)	0.0047 (0.0010)	-0.0010 (0.0011)	0.0001 (0.0010)	0.0004 (0.0009)	0.91	0.49 (0.04)	-0.68 (0.12)
Manufacture of Chemicals and Chemical Products (SBI 29/30)	-0.0335 (0.0104)	-0.0167 (0.0145)	0.0068 (0.0194)	-0.0293 (0.0201)	0.0338 (0.0182)	0.87	0.40 (0.19)	-1.04 (0.51)
Manufacture of Plastic and Rubber Products (SBI 31)	-0.0138 (0.0017)	0.0118 (0.0023)	-0.0016 (0.0026)	0.0042 (0.0027)	0.0045 (0.0023)	0.96	0.55 (0.06)	-0.64 (0.13)
Manufacture of Building mater., Earthenware, Glass (SBI 32)	-0.0301 (0.0073)	0.1685 (0.0133)	-0.0288 (0.0196)	-0.0056 (0.0181)	0.0057 (0.0153)	0.95	0.79 (0.05)	0.14 (0.20)
Manufacture of Basic Metal Products (SBI 33)	-0.0262 (0.0056)	0.0814 (0.0144)	-0.0214 (0.0170)	0.0236 (0.0160)	-0.0076 (0.0128)	0.97	0.48 (0.11)	0.56 (0.46)
Manufacture of Fabricated Metal Products (SBI 34)	-0.0106 (0.0007)	0.0122 (0.0018)	-0.0049 (0.0022)	-0.0059 (0.0019)	-0.0035 (0.0017)	0.97	0.58 (0.03)	-1.06 (0.13)
Manufacture of Machinery (SBI 35)	-0.0094 (0.0004)	0.0006 (0.0012)	-0.0023 (0.0013)	-0.0023 (0.0011)	-0.0030 (0.0010)	0.91	0.32 (0.03)	-1.50 (0.15)
Manufacture of Electrical Products (SBI 36)	-0.0070 (0.0008)	0.0090 (0.0025)	0.0037 (0.0029)	-0.0019 (0.0023)	0.0013 (0.0018)	0.92	0.49 (0.06)	-0.11 (0.28)
Manufacture of Transport Equipment (SBI 37)	-0.0090 (0.0005)	0.0095 (0.0022)	0.0030 (0.0028)	-0.0045 (0.0023)	-0.0008 (0.0018)	0.94	0.43 (0.03)	-0.53 (0.23)
Total (SBI 20/37)	-0.0124 (0.0008)	0.0225 (0.0017)	-0.0044 (0.0020)	-0.0052 (0.0019)	-0.0002 (0.0017)	0.95	0.61 (0.02)	-0.56 (0.10)

[a] R^2 is the corrected coefficient of determination, calculated with the non-transformed dependent variable $(V_E)_{rt}$.

For total manufacturing the estimated contemporary price coefficient as well as the one and two years lagged price coefficients are significant[5]. The signs of the lagged price coefficients are opposite to the sign of the contemporary price coefficient. We see that an increase of the energy price results in an increase of the energy cost share in the same year. This increase is followed by a decrease in subsequent years. For total manufacturing the scale elasticity of energy demand obtains as 0.61 with a standard deviation of 0.02. The long run price elasticity of energy demand obtains as -0.56 with a standard deviation of 0.10. This clearly implies that energy inputs are considerably reduced when prices increase. Based on aggregate time series data the Dutch Central Planning Bureau (CPB, 1984) has obtained a price elasticity of -0.54. The agreement with our results based on a fixed panel of firms is striking. It suggests that most input substitution takes place at the micro level of existing firms, and should not be attributed to the replacement of old firms going bankrupt and being replaced by new firms.

With the exception of the *chemicals and chemical products* industry, we see that in every industry the energy price has a positive influence on the energy cost share of the same year. The value of the estimated coefficient increases with the value of the energy cost share (cf. table 2.2). The speed of adjustment seems to differ between industries. Here, results are difficult to interprete becuse of the relatively large standard errors of the price coefficients. The estimated coefficient of real output is significant and has the same negative sign for all industries. Thus an increase in real output leads to a decrease in the energy cost share.

It is difficult to compare the estimated coefficients of equation (9) over industries. Therefore we consider the associated scale and price elasticities of energy demand. With the exception of the *leather products* industry all scale elasticities are significant. The highest significant

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[5] The term 'significant' without further qualification means 'significantly different from zero'. If we say that x is significantly different from y, we mean that x - y is significant, taking the estimated variances of x and y as given constants.

value is 0.79, the lowest 0.31. For 9 industries the energy price elasticity is significantly different from 0, and for 7 industries it is not significantly different from -1. With the exception of the *building materials, earthenware and glass products* industry the industries with an insignificant price elasticity are those where the number of observations is small, so that the standard deviation is high. Relatively high standard deviations, both for the scale and price elasticities are obtained for the *chemicals and chemical products* industry. As the number of observations within this sector (90) is large enough this points at a heterogeneity which is stronger than average. The only industry with a price elasticity significantly larger than unity in absolute value is the *machinery* industry: -1.50.

For total manufacturing we consider three partitions of our panel. The first one is a partition according to firm size. Large firms may have more know how and experience so that saving of energy could be easier. On the other hand large firms may be less flexible. Therefore it is interesting to obtain the scale and price elasticities differentiated with respect to firm size. The second one is a partition according to energy intensity. A priori one might guess that the incentive to reduce the input of energy is larger when the cost share of energy is higher, so that the price elasticity is, in absolute value, larger as well. The third one is a partition according to the level of investments. The idea is that if the investment/output ratio of a firm within an industry is higher, the rate of depreciation of the capital stock is higher, so that it can be replaced by more energy-extensive capital equipment. As a consequence one expects a positive relationship between the investment ratio and the possibility to save on energy costs. Tables 3.2 and 3.3 present the estimation results in terms of scale and price elasticities.

Table 3.2. Estimates of the scale and price elasticity for firms classified by firm size[a] (standard deviation between parentheses)

Number of employees	Title	Number of firms	Scale elasticity η_Q	Price elasticity η_P
10 - 50	Small firms	733	0.54 (0.04)	-0.48 (0.16)
50 - 100	Medium-sized firms	364	0.70 (0.04)	-0.61 (0.18)
100 - 500	Large firms	425	0.61 (0.04)	-0.68 (0.15)
> 500	Very large firms	121	0.62 (0.11)	-0.95 (0.43)

[a] Classification according to number of employees in 1978

The partition according to 4 firm-size classes, small, medium-sized, large and very large, shows that medium-sized firms have the highest and small firms have the lowest scale elasticity. These two scale elasticities are significantly different. When firm size increases, the price elasticity increases monotonously in absolute value. Although the differences between the estimated price elasticities are not significant, this may indicate that large firms can reduce energy costs more easily than small firms.

Table 3.3. Estimates of the scale and price elasticity for firms classified by energy intensity and investment ratio[a] (standard deviation between parentheses)

	number of firms	scale elasticity η_Q	price elasticity η_P
Partition according to energy intensity			
Energy intensity < average of all industries	1321	0.47 (0.01)	-0.80 (0.04)
Energy intensity ≥ average of all industries	322	0.67 (0.04)	-0.60 (0.14)
Partition according to investment/output ratio			
Investment/output ratio < industry average	1024	0.50 (0.03)	-0.45 (0.13)
Investment/output ratio ≥ industry average	619	0.71 (0.04)	-0.69 (0.14)

[a] Partitions according to averages over the period 1978-1986

For the partition according to energy intensity we see that the scale elasticity is significantly higher for the energy-intensive firms than for the the energy-extensive ones. The price elasticity, on the other hand, is smaller in absolute value than the price elasticity of the energy-extensive firms. The last finding may perhaps be explained by the fact that the energy share of heating and illumination of buildings in total energy consumption is higher for energy-extensive firms than for energy-intensive ones. As mentioned before, it is more easy to reduce on these types of energy use in the sphere of 'good housekeeping' than on energy use associated with the production processes themselves. The difference between the price elasticities is not significant, though.

The partition according to the investment/output ratio shows a significantly higher scale elasticity for the group of firms with a high investment/output ratio as compared to firms with a low ratio. In absolute value the price elasticity is also higher for the group of firms with an investment ratio above average. This supports the view that to some extent energy savings can only be effected by means of capital formation. Again, the difference in price elasticity in not significant, though.

4. *Summary of the most important findings*

For total manufacturing and 15 manufacturing industries an energy cost-share equation has been estimated, using a panel of individual firms over the period 1978-1986. Assuming exogenous prices and output level the cost-share equation is derived from cost minimization with a translog cost function representing the available technology. Besides real output and the price of energy, the equation contains firm-specific constants as well as time-specific industry constants. The time-specific industry constants represent non-observable input prices. Lagged energy prices are included to account for sluggishness in input substitution.

For total manufacturing we obtain a scale elasticity of energy of 0.61 and a long-term price elasticity of energy of -0.56. The estimated price coefficients show that an increase in the price of energy gives rise to an increase in the energy cost share in the same year followed by a decrease in the subsequent two years. Estimating the model for 15 manufacturing industries we obtain similar results. Scale elasticities are between 0.3

and 0.8, price elasticities are between -1.5 and -0.1. Estimated lag patterns suffer from relatively high standard errors of the estimated energy price coefficients, especially for sectors where the number of observations is small.

Partitioning total manufacturing according to firm size, we find the highest scale elasticity with the medium-sized firms and the lowest with the small firms. In absolute value the price elasticity increases monotonously from -0.5 to -1.0. Partitioning according to energy intensity, we find a higher scale elasticity and, in absolute value, a smaller price elasticity for the group of firms with above-average energy use. Partitioning, finally, according to the investment/output ratio, we find that both the scale elasticity and, in absolute value, the price elasticity depend positively on the amount of investment.

APPENDIX. REPRESENTATIVITY OF THE PANEL USED

First, we re-estimate equation (9) with a panel of 2833 firms over the period 1978-1986. We use the same firm selection criteria as for the panel of 1643 firms, except for the requirement that data on investments are known. Table A.1. compares the results obtained with the two panels. Both the scale and the price elasticities obtained are very similar for both data sets.

Table A.1. The used panel (1643 firms) compared with a panel of 2833 firms, 1978-1986

	Used panel	Extended panel
Number of firms	1643	2833
Scale elasticity	0.61	0.63
	(0.02)	(0.02)
Price elasticity	-0.56	-0.52
	(0.10)	(0.07)

Secondly, to get an idea of the effect of panel attrition we have re-estimated equation (9) with a panel of firms disappearing in the years 1984-1986. For these firms we apply the same selection criteria as for the panel of 1643 firms, except that we only consider the period 1978-1983 now. In order to make the comparison more valid we have reconstructed our panel by applying the same criteria to the firms present over the full period 1978-1986. Obviously, the reconstructed panel contains the original panel of 1643 firms. The estimation results are given in table A.2. The differences are relative small and do not point at strong selectivity effects in our estimates. Since the price elasticity tends to be higher for the disappearing firms the results do not confirm the view that disappearing firms are mainly those being unable to adjust to the higher energy costs associated with the price increases of energy inputs.

Table A.2. Firms present in 1978-1986 as compared to firms present in 1978-1983 only; selection and estimation period: 1978-1983

	Panel of firms	
	present 1978-1986	only present 1978-1983
Number of firms	1766	466
Scale elasticity	0.53	0.47
	(0.03)	(0.04)
Price elasticity	-0.56	-0.72
	(0.12)	(0.30)

REFERENCES

Berndt, E.R. and D.O. Wood, 1975, Technology, prices and the derived demand for energy, Review of Economics and Statistics, vol 57, pp 259-268.

CBS (Central Bureau of Statistics), 1978/1986a, Production statistics manufacturing industry (In Dutch), (Staatsuitgeverij/CBS-publikaties, The Hague).

CBS (Central Bureau of Statistics), 1978/1986b, Statistics on fixed capital formation in industry (In Dutch), (Staatsuitgeverij/CBS-publikaties, The Hague).

CBS (Central Bureau of Statistics), 1978/1986c, Statistics on electricity-supply in The Netherlands (In Dutch), (Staatsuitgeverij/CBS-publikaties, The Hague).

CBS (Central Bureau of Statistics), 1986, Energy-supply in The Netherlands (In Dutch), (Staatsuitgeverij/CBS-publikaties, The Hague).

CPB (Central Planning Bureau), 1984, Ceneca. A model for energy use (In Dutch), Monografie 27 (Central Planning Bureau, The Hague).

Chambers, R.G., 1988, Applied production analysis. A dual approach (Cambridge University Press, Cambridge).

Christensen, L.R., D.W. Jorgenson and L.J. Lau, 1973, Transcendental logarithmic frontiers, Review of Economics and Statistics, vol 55, pp 28-45.

Fuss, M.A., 1977, The demand for energy in Canadian manufacturing. An example of the estimation of production stuctures with many inputs, Journal of Econometrics, vol 5, pp 89-116.

Hsiao, C., 1986, Analysis of panel data (Cambridge University Press, Cambridge).

Magnus, J.R., 1979, Substitution between energy and non-energy inputs in The Netherlands 1950-1976, International Economic Review, vol 20, pp 465-484.

Pindyck, R.S., 1979, The structure of world energy demand (MIT Press, Cambridge, Massachusetts).