Firm Size and the Demand for Energy in Dutch Manufacturing, 1978—1986*

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ABSTRACT. As in most other industrialized countries the oil price shocks in the seventies led to major rearrangements in the production processes in Dutch manufacturing. The substitution of (expensive) energy consuming processes by less energy intensive ones is analyzed by means of a dynamic equation, relating the energy demand to the level of output, the price of energy and the prices of other inputs. Using a rather unique data set, consisting of panel data pertaining to several thousands of manufacturing firms, it is found that large firms can reduce energy costs more than small firms.

I. 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 no longer be ignored. Therefore, the enormous increases in Dutch energy prices in the period 1979—1985 (see Figure 1) were dramatic. These 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.

As manufacturing firms are relatively capital intensive, production processes are likely to be largely fixed, so that energy consumption patterns cannot be changed substantially in the short run. Of course, it is possible to reduce heating of work rooms and factory buildings, to insulate buildings, etc., but replacing energy-intensive capital equipment by less energy-intensive equipment is costly and takes time. At the macro-economic level input substitution may be observed when energy-intensive firms go bankrupt and are replaced by less energy-intensive ones, which are more adapted to the ruling relative input prices. However, at the micro-economic level the important question is how much flexibility the already existing firms have in their use of energy over a period of two to five years. Moreover, it is interesting to investigate whether small firms have more or less flexibility in their use of energy than large firms.

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. Then the demand for inputs, including energy, depends on the level of output, the substitution possibilities among inputs within 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 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 using 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.

Estimating the energy cost-share equation must answer the following questions. By which amount and how fast do firms reduce their demand for energy when prices increase? Does the reaction depend upon the size of the firm?

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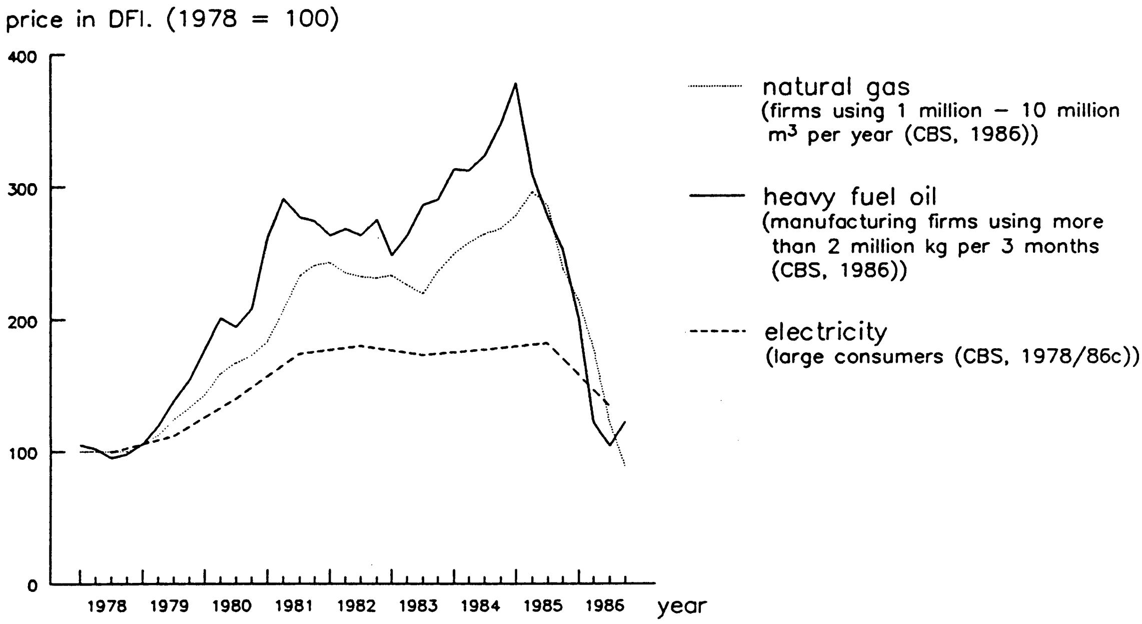

Fig. 1. Dutch energy prices, 1978—1986.

The outline of this article is as follows. In Section II the energy cost share equation is derived. In Section III we describe our data, concentrating on the construction of the panel, the firm-size classes, the energy prices and the changes in cost share, output and prices. In Section IV we present the estimation results. In Section V, finally, we give a summary of the most important findings of our study.

II. Cost-share equation of energy

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

$$Q = Af(K, L, E, M), \qquad (1)$$

representing the underlying technology of a firm, where

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

For practical reasons we omit firm and time indices in the first part of this subsection. 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

$$\begin{aligned} C &= C(Q/A, p_K, p_L, p_E, p_M) \\ &= \min_{K,L,E,M} \{p_K K + p_L L + p_E E + \\ &\quad + p_M M : f(K, L, E, M) = Q/A\}, \end{aligned} \qquad (2)$$

where

C: total cost of production, as a function of Q/A, p_K, p_L, p_E and p_M
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),

$$\log C = \alpha_0 + \alpha_Q \log(Q/A) + \sum_i \alpha_i \log(p_i) + \\ + \frac{1}{2}\gamma[\log(Q/A)]^2 + \\ + \log(Q/A)\left\{\sum_i \gamma_{iQ}\log(p_i)\right\} + \\ + \frac{1}{2}\sum_i\sum_j \gamma_{ij}\log(p_i)\log(p_j), \quad (3)$$

where

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

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

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

where

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

Combining (3) and (4) we obtain

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

It is not possible to estimate the four cost share equations of the system simultaneously, because data on capital and prices of inputs other than energy are not available. Therefore, only the energy cost share equation will be estimated. Since prices of inputs other than energy will not be included explicitly in the equation to be estimated, we will 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

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

where

r: firm index, $r = 1, \dots, R$,

t: time index, $t = 1, \dots, T$.

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 consider $(p_L)_{rt}$ to be missing, too. For the missing input prices jointly, we introduce a time-specific constant per industry

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

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 homogeneous. 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 be similar for firms within the same industry.

Substitution of (7) into (6) gives

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

where

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

For notational purposes we introduce a generalized difference operator Δ which takes deviations from means over time for each firm and over firms in each industry, and which for a general variable y_{rt}, is defined by

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

where

$$y_{r.} \equiv (1/T) \sum_{t=1}^{T} y_{rt}$$

(average over time for firm r),

$$y^s_{.t} \equiv (1/R_s) \sum_{r \in W_s} y_{rt}$$

(average over firms in industry s),

$$y^s_{..} \equiv (1/T)(1/R_s) \sum_{t=1}^{T} \sum_{r \in W_s} y_{rt}$$

(overall average in industry s),

R_s: number of firms in industry s,

W_s: set of (indices of) firms in industry s.

Applying Δ to (8) we can sweep out the time-invariant firm constants α_r and the time-specific industry constants β_{st}; the resulting equation can then be estimated by Ordinary Least Squares (OLS) on the transformed variables. The obtained estimator is the so-called covariance estimator (Hsiao, 1986, p. 53).

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 many 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 energy price trends are the key factor in explaining changes in energy shares, we introduce dynamics by adding lagged energy prices.

Applying the generalized difference operator Δ to Equation (8) with the lagged energy prices added, the equation becomes

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

III. Data

1. *Panel construction*

The Netherlands Central Bureau of Statistics collects data on individual firms in manufacturing. An annual survey asks 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 electricity and natural-gas inputs. All firms with 10 or more employees are observed; smaller ones are excluded. For about seventy industry groups aggregated data are published annually in the Production Statistics (CBS, 1978/1986a).

In the period 1978—1986 the number of firms is approximately 8500 per year. Pooling the annual data, we have constructed our panel by selecting the firms satisfying the following selection rules:[1]

- a firm is present in each year in the period 1978—1986;
- the value and volume of the inputs of natural gas and electricity are reported;
- the implicit prices (unit values) of natural gas and electricity do not exceed the (average) energy prices charged to households by more than 25% in any year;
- for each year in the period 1979—1986 the price, as well as the cost share of energy, is between 0.33 and 3 times the price and the cost share of energy of the year before.

The first two rules are obvious; the last two are justified by errors of measurement. The bounds in the last two selection rules have been selected in such a way that the obvious errors of measurement disappear, whereas the variation in prices due to contracts and regional price differences does not disappear.

The above requirements give a time-series of 9 years of a cross-section of 2776 firms.

2. *Firm-size classes*

We divide total manufacturing in firm-size classes according to the number of employees in 1978. We choose the following four firm-size classes:

- *small firms* with 10 to 50 employees;
- *medium-sized firms* with 50 to 100 employees;
- *large firms* with 100 to 500 employees;
- *very large firms* with 500 and more employees.

As discussed in the previous subsection, the lower bound of the smallest size class is necessarily 10 employees, because there are no observations of firms with less than 10 employees. As lower bounds of the next two size classes we choose 50 and 100 employees, respectively. In the Netherlands such a subdivision is often made. All firms with less than 100 employees, for instance, constitute the so-called group of the small and medium-sized enterprises (SME's). We choose 500 employees as the lower bound of the largest size class. This bound is often used in the United States, where in many studies small firms are defined as firms with less than 500 employees.

3. *Electricity and natural-gas prices*

In the Netherlands the price a firm pays for electricity or natural gas generally depends on the quantity it consumes: as consumption increases, the average price decreases. Prices and quantities can be agreed upon in special contracts between a firm and its supplier.

The average prices of electricity and natural gas for each size class and total manufacturing are presented in Table I. The number of firms and the energy intensity in 1978 are also shown. First, we consider size classes. Taking into account that energy intensity does not differ much between size classes, we expect that on average small firms will use a smaller quantity of energy than large firms. Consequently, it is not surprising that for each year during the period 1978—1986 firms in a lower size class generally pay more on average for both electricity and natural gas than firms in a higher size class. Secondly, we consider prices over time. We can distinguish three sub-periods:

- in 1978—1982 the electricity price increases by about 60% and the natural gas price by more than 100%;
- in 1982—1985 the electricity price stabilizes at the level reached in 1982, whereas the natural gas price continues to rise, though at a slower rate (about 19% in total);
- in 1986 the electricity price decreases by about 15% and the natural gas price by about 10% (on average). The natural gas price decreases much more for large energy consumers than for small consumers.

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

4. *Cost share, output and prices*

For the four size classes and for total manufacturing 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 II. The cost share of energy should be defined as energy costs divided by total costs. However, total costs are not available, so we take the value of gross output as the denominator when computing cost shares.

Table II shows that in 1978—1986 the increase of the cost share of energy is lower than the increase of the relative price index of energy.[2] For total manufacturing we measure a 36% increase of the relative energy price in 8 years, while the increase of the cost share is 27%. This indicates that on average firms reduced their demand for energy relative to real output by 7%.[3] However, the amount of reduction varies between size classes. A reduction in energy use of 8 and 10% can be observed for the medium-sized and large firms, respectively. The small and very large firms on the other hand have reduced their demand with only two-third of those values, i.e., 5 and 6%, respectively. On average, real output of the small and medium-sized firms increase with 31%, real output of the large firms with 18% and real output of the very large firms with only 7%. So there seems to be no relation between the reduction in energy use and the growth of real output.

IV. Estimation results

We have estimated Equation (9) for the period 1978—1986. As discussed before, some data problems had to be solved.

First, capital costs are not available. So we took gross operating surplus as a proxy for capital costs. Gross operating surplus is equal to the sum of interest, capital consumption and profits, while profits consist of a reward for capital of the owners and excess profits. If output markets are competitive and there is free entry and exit, then excess profits are zero and capital costs are *equal*

TABLE I
Prices of electricity and natural gas for each size class (firm averages)

		Size class (number of employees)				Total
		10–50	50–100	100–500	⩾500	⩾10
Number of firms[a]	1978	1444	606	604	122	2776
Energy intensity[b]	1978	0.019	0.019	0.023	0.024	0.020
		guilders (standard deviation between parentheses)				
Price of electricity[c]	1978	14.7 (2.8)	14.2 (2.9)	12.9 (2.8)	11.5 (2.9)	14.1 (3.0)
	1979	16.1 (2.7)	15.3 (2.9)	14.0 (3.1)	12.3 (2.6)	15.3 (3.0)
	1980	18.5 (2.7)	17.7 (2.9)	16.4 (3.1)	14.7 (2.7)	17.7 (3.0)
	1981	21.8 (2.9)	21.2 (3.1)	19.8 (3.5)	18.2 (3.3)	21.1 (3.3)
	1982	23.4 (2.9)	22.4 (3.4)	20.9 (3.4)	19.0 (3.3)	22.4 (3.4)
	1983	23.4 (3.1)	22.2 (3.4)	20.6 (3.8)	18.5 (3.7)	22.3 (3.6)
	1984	24.0 (3.3)	22.7 (3.9)	21.1 (4.1)	18.8 (4.1)	22.9 (3.9)
	1985	24.3 (3.3)	22.7 (3.7)	21.1 (4.1)	19.1 (4.2)	23.0 (3.9)
	1986	21.2 (3.2)	18.9 (3.5)	17.3 (3.9)	15.6 (3.6)	19.6 (3.9)
Price of natural gas[d]	1978	21.4 (2.9)	21.2 (3.0)	20.3 (2.9)	18.6 (2.5)	21.0 (3.0)
	1979	23.8 (2.7)	24.0 (2.6)	23.2 (2.9)	20.8 (2.4)	23.6 (2.8)
	1980	29.4 (2.7)	29.3 (2.6)	29.0 (2.8)	27.6 (2.9)	29.2 (2.8)
	1981	38.6 (3.5)	39.1 (3.3)	38.7 (3.6)	37.8 (3.7)	38.7 (3.5)
	1982	44.6 (3.6)	45.2 (3.4)	45.1 (3.2)	43.8 (2.8)	44.8 (3.5)
	1983	48.1 (3.7)	48.0 (3.3)	47.1 (3.8)	44.4 (3.2)	47.7 (3.7)
	1984	51.4 (3.5)	51.6 (3.2)	50.8 (3.5)	48.1 (3.4)	51.2 (3.5)
	1985	53.4 (3.3)	53.7 (3.7)	53.2 (3.8)	50.2 (3.4)	53.3 (3.6)
	1986	50.2 (6.2)	48.7 (8.9)	44.7 (9.9)	36.8 (9.2)	48.0 (8.5)

[a] Number of firms in panel.
[b] Energy costs divided by the value of gross output.
[c] Price of electricity in guilders per 100 kWh.
[d] Price of natural gas in guilders per 100 m^3.

TABLE II
Development of cost share of energy,[a] real output[b] and price of energy[c] by firm size (firm averages)

Size class (number of employees)		Cost share of energy				Real output				Relative price of energy			
		1980	1982	1984	1986	1980	1982	1984	1986	1980	1982	1984	1986
		Indices 1978 = 100											
10– 50	Small firms	122	152	149	134	111	108	116	131	121	152	157	141
50–100	Medium-sized firms	121	151	145	123	110	110	117	131	121	154	157	134
100–500	Large firms	124	150	145	118	107	106	109	118	124	159	159	131
⩾500	Very large firms	127	158	152	119	105	100	102	107	127	164	160	126
⩾ 10	Total	122	151	147	127	109	108	114	127	122	155	157	136

[a] Energy costs divided by the value of gross output.
[b] Nominal output deflated by the three-digit output price index.
[c] Price of energy relative to price of output, cf. Note 2.

to gross operating surplus (and total costs are equal to total output). If output markets are not fully competitive, differences in competition could affect the dependent variable. Other things being equal, industries with higher excess profits will have smaller energy revenue shares. Then capital costs and gross operating surplus are *not equal.* For this reason we will refer to the 'cost' share as energy share in the following section of this article. However, differences between firms but constant in time and differences in time but constant between firms within an industry are partly absorbed by the firm constants and the time-specific industry constants. Therefore, we think that the approximation of capital costs by gross operation surplus does not greatly affect our results.

Secondly, the lowest level of aggregation at which output price index numbers are available is the three-digit level of the Dutch Standard Industrial Classification (SBI). We used these price index numbers for deflating nominal output.

Thirdly, the energy price of a firm was calculated as a chained Laspeyres index of the prices of the two most important fuels, electricity and natural gas. For natural gas average prices do not equal marginal prices since these prices follow a declining rate schedule (quantity x_1 for price p_1, quantity x_2 for price $p_2 < p_1$ after consuming quantity x_1, etc.). In Kleijweg *et al.* (1989), Equation (9) has also been estimated with marginal prices instead of average prices. For total manufacturing the results were almost identical; therefore here we use average prices only.

Under these assumptions and after adding a disturbance term, Equation (9) was estimated for each size class as well as for total manufacturing.[4] We also calculated the elasticity of energy demand with respect to the level of output, η_Q, and the long-run own price elasticity of energy demand, η_p.[5] The estimation results are presented in Table III.

Note that η_Q is not the usual scale elasticity of energy. It does not represent cross-sectional variation as such, which is represented by a firm-specific time-invariant constant in Equation (8). Therefore, η_Q mainly represents scale effects over time.

For total manufacturing, the estimated contemporary price coefficient as well as the one and two years lagged price coefficients, are significant.[6] The signs of the lagged price coefficients are the opposite of the sign of the contemporary price coefficient. We see that an increase in energy price initially results in an increase in energy share in the same year.[7] This increase is followed by a decrease in subsequent years. For total manufacturing the scale elasticity of energy demand is 0.63 with a standard error of 0.01. The long-term price elasticity of energy demand is −0.46 with a standard error of 0.06. This clearly implies that energy inputs are reduced considerably when prices increase. Based on aggregate time series

TABLE III

Parameter estimates for the energy share equation (9) by size class (standard errors between parentheses)

Size class		Coefficients					$R^{2\,a}$	Elasticities	
		γ_{EQ}	γ_{EE}	$\gamma_{EE,-1}$	$\gamma_{EE,-2}$	$\gamma_{EE,-3}$		η_Q	η_p
10– 50	Small firms	−0.0109 (0.0005)	0.0202 (0.0015)	−0.0039 (0.0015)	0.0003 (0.0014)	0.0014 (0.0012)	0.06	0.61 (0.02)	−0.33 (0.09)
50–100	Medium-sized firms	−0.0093 (0.0008)	0.0240 (0.0021)	−0.0076 (0.0024)	−0.0066 (0.0023)	−0.0015 (0.0020)	0.07	0.66 (0.03)	−0.67 (0.13)
100–500	Large firms	−0.0122 (0.0008)	0.0234 (0.0018)	−0.0054 (0.0023)	−0.0029 (0.0021)	−0.0053 (0.0019)	0.11	0.60 (0.03)	−0.65 (0.11)
⩾500	Very large firms	−0.0094 (0.0013)	0.0281 (0.0029)	−0.0027 (0.0043)	−0.0035 (0.0039)	−0.0061 (0.0030)	0.19	0.71 (0.04)	−0.49 (0.17)
⩾ 10	Total	−0.0106 (0.0004)	0.0230 (0.0009)	−0.0052 (0.0011)	−0.0020 (0.0010)	−0.0011 (0.0009)	0.08	0.63 (0.01)	−0.46 (0.06)

[a] R^2 is the corrected coefficient of determination, calculated with the transformed dependent variable $(V_E)_{rt}$. This is the coefficient of determination that belongs to the non-dummy part of the model. The R^2 belonging to our original equation, i.e. the equation with dummy variables for technology and non-energy input prices, varies from 0.95 to 0.97.

data, the Dutch Central Planning Bureau (CPB, 1984) obtained a price elasticity of −0.54, which corresponds closely to our results based on a fixed panel of firms. It suggests that most input substitution takes place at the micro level of existing firms, and should not be attributed to the replacement of inefficient firms by new and more efficient ones.

For all size classes we see that the energy price has a positive influence on the energy share of the same year.[8] The lagged coefficients show that the speed of adjustment seems to differ between size classes. For small firms the estimated one-year lagged price coefficient is the only lagged price coefficient that is significant. There is no further adjustment in subsequent years. For the other three size classes the two and/or three years lagged price coefficients, too, influence the energy share, which implies a longer period of adjustment, especially for large and very large firms. For all size classes the estimated coefficient of real output is significant and has a negative sign. Thus an increase in real output leads to a decrease in the energy share.

All scale elasticities of energy are significant. Very large firms have the highest scale elasticity. The classes small and large show the lowest scale elasticities. Only the scale elasticity of very large firms differs significantly from the scale elasticities of small and large firms.

For all size classes the price elasticities are between 0 and −1 and they are significantly different from 0 as well as −1. Measured in absolute value the price elasticity is lowest for small firms, while medium-sized and large firms have the highest. For very large firms we find a value of the price elasticity exactly between the elasticity of small firms and the elasticity of medium-sized and large firms. The price elasticity of small firms differs significantly from the price elasticities of medium-sized and large firms. Although the difference between the estimated price elasticities of small and very large firms is not significant, this may indicate that large firms can reduce energy costs more than small firms. Large firms may have more know-how and experience so that they have more possibilities to save energy. The longer period of adjustment of large firms can then be explained by the fact that it takes time to realize savings.

Untill now we have considered total manufacturing and the division of total manufacturing in four size classes. Now we consider the 6 manufacturing industries with the highest number of firms. These 6 industries (food, beverages and tobacco, wood and wood products, printing and publishing, building materials, earthenware and glass, fabricated metal products, and machinery) contain almost 75% of all manufacturing firms. We divide these industries in two size classes: the small firms (10 to 50 employees) and the remaining firms, the medium-sized, large and very large firms (50 and more employees). A division in more size classes is hardly possible, since the number of observations would become too small. In Table IV we present the estimation results in terms of scale and price elasticities.

We see that there is a considerable variation in scale coefficients over industries. Within each industry the scale elasticities of the two size classes are not significantly different, though.

The price elasticities fluctuate substantially over industries as well as over size classes within industries. The reactions on increases of the energy price are widely divergent. In three industries (food, beverages and tobacco, fabricated metal products, and machinery) the price elasticity of small firms is significantly lower than the price elasticity of the group of medium-sized, large and very large firms. In two other industries (wood and wood products, and printing and publishing) it is just the reverse. In the remaining industry (building materials, earthenware and glass) the price elasticities of the two size classes are not significantly different.

V. Conclusion

An energy cost-share equation has been estimated for total manufacturing, for firm-size classes, and for manufacturing industries, using a panel of individual firms for 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. Because of the lack of capital data we took total output as a proxy for total costs. In addition to real output and energy prices, 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 0.6 and a long-run price elasticity of energy of −0.5. The estimated price coefficients show that an increase in the price of

TABLE IV

Estimates of the scale and price elasticity for firms by size and industry (standard errors between parentheses)

Industry[a]	Scale elasticity (η_Q) per size class			Price elasticity (η_p) per size class			Number of firms per size class		
	10—50	⩾50	⩾10	10—50	⩾50	⩾10	10—50	⩾50	⩾10
Manufacture of food, beverages and tobacco (SBI 20/21)	0.71 (0.03)	0.72 (0.04)	0.72 (0.03)	−1.20 (0.12)	−0.65 (0.14)	−0.81 (0.09)	307	262	569
Manufacture of wood and wood products (SBI 25)	0.41 (0.05)	0.30 (0.07)	0.40 (0.04)	−0.66 (0.20)	−1.84 (0.27)	−1.06 (0.16)	93	45	138
Printing and publishing (SBI 27)	0.55 (0.03)	0.48 (0.05)	0.54 (0.03)	−0.40 (0.12)	−1.10 (0.15)	−0.61 (0.09)	240	119	359
Manufacture of building materials, earthenware and glass (SBI 32)	0.70 (0.04)	0.78 (0.06)	0.74 (0.04)	0.32 (0.19)	−0.29 (0.24)	0.09 (0.15)	73	80	153
Manufacture of fabricated metal products (SBI 34)	0.55 (0.03)	0.59 (0.03)	0.58 (0.02)	−1.46 (0.14)	−0.48 (0.16)	−0.96 (0.10)	255	176	431
Manufacture of machinery (SBI 35)	0.40 (0.03)	0.36 (0.03)	0.39 (0.02)	−1.55 (0.17)	−0.91 (0.16)	−1.17 (0.11)	195	199	394

[a] Following the Dutch Standard Industrial Classification (SBI) of 1974.

energy leads to an increase in the energy share in the same year, followed by a decrease in the subsequent three years.

Partitioning total manufacturing according to firm size, we find that small firms are able to adjust more quickly to energy price changes than large firms and that large firms can reduce energy costs more than small firms. In absolute value the price elasticity of the small firms is the lowest one and the elasticity of the medium-sized firms is the highest one.

Finally, we have considered some manufacturing industries. Within industries we find no differences between the scale elasticity of the small firms and the scale elasticity of the group of medium-sized, large and very large firms. The price elasticities, however, differ between these two size classes within industries, although not in a systematic way.

Notes

* This article reports on research carried out in the MOPS-project. Participants of MOPS are the Netherlands Central Bureau of Statistics, the Research Institute for Small and Medium-sized Business in The Netherlands, and the Erasmus University Rotterdam. The views expressed in this article do not necessarily reflect the policies of the Netherlands Central Bureau of Statistics.

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[1] Investment data were also required in Kleijweg *et al.* (1989). However, the estimation results showed that energy demand was hardly influenced by investments. For this reason we drop this selection criterion here, so that a larger panel remains.

[2] The price index of energy is a chained Laspeyres 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% in 1978 and 94.1% in 1986 (averages per firm). The relative price index of energy is the price index of energy divided by the three-digit output price index. The three-digit level is the three-digit level of the Dutch Standard Industrial Classification (SBI) of 1974. At this level of aggregation there are approximately 70 output price indices.

[3] Which is equal to the cost share of energy divided by the relative price of energy.

[4] The industry level at which we take time-specific constants, is the two-digit SBI level. There are 15 two-digit groups in our panel. Some two-digit groups are three-digit groups in the ISIC classification, other groups are combinations of three-digit groups in the ISIC classification.

[5] $$\eta_Q = \frac{\partial \log(E)}{\partial \log(Q)} = \frac{\gamma_{EQ}}{\bar{V}_E} + 1;$$

$$\eta_p = \frac{\partial \log(E)}{\partial \log(p)} = \frac{\gamma_{EE} + \gamma_{EE,-1} + \gamma_{EE,-2} + \gamma_{EE,-3}}{\bar{V}_E} - 1 + \bar{V}_E;$$

$\bar{V}_E$ is the (unweighted) average of the energy cost share V_E over firms and time.

[6] 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 true variances of x and y to be equal to the estimated variances.

[7] All coefficients are discussed under the 'ceteris paribus' condition.

[8] Note first that cross-sectional variation between firms is estimated by a firm-specific time-invariant constant. This constant represents the energy efficiency of a firm, which may vary across firms in the same two-digit industry (for instance between small and large firms). Note secondly that, with exception of the largest size class, for each size class the distribution of firms over industries is rather equal. In the size class 'very large firms' there is a small number of firms, with an over-representation of firms from the chemicals and chemical products industry. Therefore, industry effects cannot play an important role in the estimation results of the small, medium-sized and large firms but can be of significance for the estimation results of the very large firms.

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