The demand for energy in the large-scale manufacturing sector of Pakistan

Fakhre Mahmud and Salim Chishti

The extent of interfuel substitution, as well as substitution between energy and non-energy inputs, in the large-scale manufacturing sector of Pakistan has been examined. The model has been estimated in two stages. In the first stage input demand for various energy components is estimated and hence an aggregate Divisia index is constructed. In the second stage this index is used as an instrument to estimate aggregate input demand for capital, labour and energy along with their price and substitution elasticities. It seems that there is little interfuel substitution. The results also show that energy and labour are substitutes while energy and capital are complement.

Keywords: Energy; Manufacturing; Pakistan

Pakistan's large-scale manufacturing sector has been growing at over 7% per annum. The sector consumes about 35% of total commercial energy, demand for which is growing at over 6% per annum. Energy has been a major constraint on the growth of the sector (Pasha *et al* [10]). Pakistan is a net oil-importing country, spending about 22% of its export earnings. While serious strides are underway to cope with the energy constraint from the supply side, in the past efforts have been made to adopt demand management policies to make interfuel, as well as fuel and non-fuel substitutions. However, there are few analytical studies to evaluate the impact of demand management policies. The purpose of this paper is to study the substitution between different carriers of energy as well as between energy and non-energy inputs in the manufacturing sector of Pakistan.

The model and data

Following Fuss [4] the model is estimated in two stages. In the first stage input demands for various energy

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components are estimated and hence an aggregate price Divisia index for energy is developed. In the second stage this index is used as an instrument variable to estimate aggregate input demand for capital, labour and energy along with their price and substitution elasticities.

It has been assumed that the aggregate production process can be represented by a translog production process with three inputs, namely capital, labour and energy which is weakly separable in energy. Invoking duality relations in production and cost, this can be equivalently represented by a translog cost function which is also weakly separable and can be written as:

$$\ln C = \ln \alpha_o + \sum \alpha_i \ln P_i + \alpha_Q \ln Q + \tfrac{1}{2} \sum_i \sum_j v_{ij} \ln P_i . \ln P_j$$

$$+ \sum v_{iQ} \ln Q . \ln P_i + \tfrac{1}{2} v QQ (\ln Q)^2$$

$$i,j = E \text{ (energy)}, N \text{ (labour)}, K \text{ (capital)} \qquad (1)$$

where P_E is an aggregate price index of all energy components. Partially differentiating Equation (1), invoking Shephard's lemma and imposing homogeneity, adding up and symmetry restrictions yields the following input demand equations:

$$S_i = \alpha_i + \sum_j \tau_{ij} \ln P_j + \tau_{iQ} \ln Q$$

$$i, j = E, N, K \qquad (2)$$

Corresponding to Equation (2) the Allen–Uzawa partial substitution elasticities are given by:

$$\sigma_{ij} = \frac{\tau_{ij} + S_i S_j}{S_i S_j} \quad i, j = E, N, K; \; i = j$$

$$\sigma_{ii} = \frac{\tau_{ii} + S_i^2 - S_i}{S_i^2} \quad i = E, N, K \tag{3}$$

and price elasticities are given by:

$$E_{ij} = S_j \sigma_{ij}$$

$$E_{ii} = S_i \sigma_{ii} \tag{4}$$

Before estimating the above model a similar translog sub-module in energy components has been estimated. More specifically the translog cost function corresponding to various energy components may be written as follows:

$$\ln P_E = \ln \beta_o + \sum_i \beta_i \ln P_{Ei} + \sum_i \sum_j \beta_{ij} \ln P_{Ei} \ln P_{Ej} \tag{5}$$

where P_E is the aggregate price index of energy but can also be viewed as the cost per unit of energy to the optimizing agent.

The cost minimizing input demand functions corresponding to Equation (5), after imposing homogeneity, symmetry and adding-up restrictions are given by:

$$S_{Ei} = \beta_i + \sum_j \beta_{ij} \ln P_{Ej} \tag{6}$$

First the sub-module consisting of Equations (5) and (6) has been estimated and hence interfuel substitution and price elasticities are estimated. In addition, the parameter estimates are substituted in Equation (5) to obtain an aggregate price index for energy which in turn has been used as an instrument variable in the estimation of the aggregate production function. More specifically P_E in Equations (1) and (2) has been replaced by the instrument variable thus obtained and then these two equations are estimated.

Annual time series data for the period 1960–80 have been used. All data on quantities and prices, except for energy have been taken from Naqvi *et al* [9]. The data on energy components, both quantities and prices have been taken from the *Energy Year Book*.[1] All energy quantities have been converted into Btus.

Results

Zellner's iterative estimation procedure has been used. The invariance of the estimates of the parameters has

[1] It includes only commercially purchased energy and therefore does not account for energy (especially electricity) which is self-generated by industry. However, this component has become relatively more significant in recent years. The data on gas excludes the use of gas as a feedback in fertilizers.

been ensured in both the energy sub-module as well as in the aggregate model by estimating each of the models three times, dropping one share equation at a time.

The parameter estimates of the energy sub-module are presented in Table 1. Eleven out of twelve parameters are significant at the 1% level. The own- and cross-price elasticities are presented in Table 2. Own-price elasticities for electricity and oil take correct signs and are significant at the 5% level. The price elasticity for gas is positive, but insignificant, at the 5% level. Cross-price elasticity between electricity and gas is negative but insignificant. This is also the case with the

Table 1. Parameter estimates of the share equations (inter-fuel).

β_E	0.3386
	(5.55)
β_{TE}	0.00627
	(2.50)
β_G	0.2924
	(8.49)
β_{TG}	0.00939
	(8.34)
β_O	0.3688
	(7.91)
β_{TO}	−0.01616
	(−6.76)
β_{EE}	0.1745
	(4.13)
β_{GG}	0.1894
	(9.01)
β_{OO}	0.0942
	(2.99)
β_{EG}	−0.1348
	(−5.87)
β_{EO}	−0.0396
	(−1.21)
β_{GO}	−0.0546
	(−4.49)
£	101.455

Note: E = electricity, G = gas and O = oil.

Table 2. Inter-fuel price elasticities

$\tilde{n}_{EE}$	−0.1144
	(−1.59)
$\tilde{n}_{GG}$	+0.1152
	(1.14)
$\tilde{n}_{OO}$	−0.3304
	(−2.11)
$\tilde{n}_{EG}$	−0.01963
	(−0.503)
$\tilde{n}_{EO}$	0.134
	(2.389)
$\tilde{n}_{GO}$	−0.0598
	(−1.02)
$\tilde{n}_{GE}$	−0.0554
	(−0.503)
$\tilde{n}_{OE}$	0.393
	(2.40)
$\tilde{n}_{OG}$	−0.062
	(−1.02)

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Table 3. Parameter estimates with instrument for P_E (P_E).

α_O	−1.405	τ_{NK}	−0.0747
	(−0.311)		(−2.22)
α_q	1.12	τ_{NE}	−0.00532
	(0.966)		(−0.706)
α_n	0.279	τ_{KE}	−0.0595
	(1.123)		(−12.49)
α_K	0.7544	τ_{qn}	−0.07789
	(3.32)		(−2.24)
α_e	−0.0339	τ_{qe}	−0.0359)
	(−0.897)		(−6.61)
τ_{NN}	0.08009	τ_{qk}	0.1138
	(2.14)		(3.62)
τ_{KK}	0.1342	αt	−0.0989
	(4.356)		(−4.13)
τ_{EE}	0.0647	τt_n	0.009164
	(9.69)		(3.56)
τt_K	−0.0138	τt_e	0.00464
	(−5.89)		(10.55)

Table 4. Price and substitution elasticities between factor inputs, using P as instrument.

	Elasticity	*t*-ratio
σ_{NN}	−3.3653	−4.5539
σ_{EE}	−0.14096	−1.7919
σ_{KK}	−0.24978	−3.6724
σ_{NE}	0.39729	4.3890
σ_{EN}	0.071998	4.4679
σ_{KE}	−0.047005	−4.3471
σ_{EK}	−0.25632	−4.3475
σ_{NK}	0.29330	4.0557
σ_{KN}	0.29679	3.9816
S_{NE}	0.86190	4.416
S_{KE}	−0.5627	−4.306
S_{NK}	0.64387	4.0218

Note: E = energy, N = labour, K = capital.

cross-price elasticity between oil and gas. Electricity and oil are substitutes. However, the degree of substitution is low. Generally, it seems that there has been little interfuel substitution in the manufacturing sector of Pakistan.

In the second stage the aggregate model consisting of Equations (1) and (2) has been estimated using P_e obtained from Equation (5) as instrument for P_E. The parameter estimates are presented in Table 3.

Thirteen out of eighteen coefficients are significant at the 5% level. The corresponding price and substitution elasticities are presented in Table 4. All the own-price elasticities take correct signs and are significant at the

5% level. However, the degree of price responsiveness is not high. Particularly the price elasticity of energy demand is quite low.[2] The cross-price elasticities between employment and energy are positive and significant. The degree of substitution as depicted by the corresponding substitution elasticity is sizable. This result is similar to earlier such studies for other countries (Apte [1] and Vashist [11]).

The more interesting result is the negative cross-price elasticity between capital and energy. The corresponding substitution elasticity is also negative and significant at the 5% level. It implies that capital and energy are complements. There has long been controversy about energy–capital complimentarity. Most of the studies which used annual time series data have found energy and capital to be complements (Berndt and Wood [2], Fuss [4], Hudson and Jorgenson [7] and Magnus [8]). However, some inter-country and cross-sectional studies report the two inputs as substitutes (Griffin and Gregory [6]), one of the explanations, which seems more plausible in our case, relates to the time horizon for which the production relation is estimated.[3] In the short run, if other inputs can be substituted against the capital–energy aggregate, capital and energy may be complements. In our case also the period covered may not be long enough to let the energy–capital adjustments work out fully.

Conclusion

The purpose of this study was to estimate the extent of interfuel substitution as well as substitution between energy and non-energy inputs in the large-scale manufacturing sector of Pakistan. The results do not provide evidence for significant interfuel substitution. As regards the substitution between energy and other inputs, our results indicate that energy and labour are substitutes whereas energy and capital are complements.

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