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The energy demand in the manufacturing sector of Pakistan: some further results

Syed F. Mahmud*

Bilkent University, Faculty of Economics, Administrative and Social Sciences, 06533 Bilkent, Ankara, Turkey

Abstract

The purpose of this study was to re-examine the role of energy in the manufacturing sector of Pakistan using a Partial Equilibrium Approach. GL restricted cost function along with the factor demand equations were estimated using Zellner's iterative procedure. Higher energy prices do not seem to adversely affect investment in capital. Substitution possibilities between energy and non-energy inputs are very limited and therefore energy price hikes may directly affect the cost of production. Inter-fuel cross price elasticities indicate that there are substitution possibilities between electricity and gas.

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Keywords: Energy; Manufacturing; Pakistan

1. Introduction

Energy has been a perennial constraint on the growth of the industrial sector of Pakistan. In a recent study (Pasha et al., 1990), it is reported that load-shedding has caused a loss of approximately 6% of the value-added in the manufacturing sector. The manufacturing sector consumes approximately 35% of the total commercial energy. In short, energy has been one of the major growth constraints for the manufacturing sector. At the policy level serious efforts are underway to cope with the constraints on the supply side of energy. Also, various demand management policies that encourage inter fuel as well as fuel/non-fuel substitution have been adopted.

* *E-mail address*: syed@bilkent.edu.tr (S.F. Mahmud).

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There are very few analytical studies which have evaluated the impact of demand management policies on the manufacturing sector of Pakistan. Pasha et al. have analyzed the impact of power load shedding on the industrial sector of Pakistan. Chishti and Mahmud (1990) studied the substitution possibilities between energy and other non-energy inputs in the manufacturing sector of Pakistan within a full equilibrium framework using time series data (under the assumption of complete and instantaneous adjustment of all inputs). Iqbal (1986) has used KLE Translog function for pooled data for the 16 manufacturing industries of Pakistan. The assumption of instantaneous adjustment of all inputs, i.e. all inputs are instantaneously adjustable, may not be very useful under sharp and unexpected increases in the energy prices. In such cases the characteristics of the firm's short-run behavior during the initial impact of the shock may differ from those when full adjustment to long-run equilibrium is attained.[1] There are at least two distinct alternative approaches to the full equilibrium static model that have evolved recently, making a distinction between responses of the firms in temporary or short-run equilibrium from full equilibrium. In both the approaches fixity of some factor inputs such as capital has been acknowledged (see, e.g. Morrison, 1988). The silent feature of the first approach is the explicit recognition of the existence of adjustment costs in the firms' optimization problem, rendering full adjustment of some of the factor inputs too costly. Dynamic firm's behavior in the presence of adjustment cost have been theoretically extended and empirically tested. The second approach while recognizing the fixity of some of the factor inputs does not explicitly incorporate dynamic adjustments explicitly into the firms' optimization problem. These are referred to as partial static models. In this paper we re-examine the substitution possibilities between energy and non-energy inputs in a partial equilibrium model.[2]

2. Model

The model introduces energy directly into the production function as a factor input beside capital and labor. It further assumes that capital is a quasi-fixed factor. Following Morrison (1988), we specify a GL restricted or variable cost function.[3] In general, for T variable inputs with prices (p_i) and capital (K) as the only quasi-fixed factor, the GL restricted cost function is specified as follows:

[1] For instance the oil and electricity prices rose by 29% and 37% in the year 1974, respectively, in Pakistan. There were other periods of sharp increases in energy prices. In 1981 and 1991 oil prices went up by 53% and 36%, respectively.

[2] Dynamic model is fairly non-linear in parameters compared to a Partial Equilibrium Model and therefore only Partial Equilibrium Model is estimated at this stage.

[3] Unlike Translog cost functions, it is easier to get long-run analytical solutions of the quasi-fixed factors with GL specification.

$$G = Q\left[\sum_i \sum_j \alpha_{ij} p_i^{0.5} p_j^{0.5} + \sum_i \sum_m \beta_{im} p_i Z_m^{0.5} + \sum_i p_i \sum_m \sum_n \phi_{mn} Z_m^{0.5} Z_n^{0.5}\right]$$
$$+Q^{0.5}\left[\sum_i \beta_{ik} p_i K^{0.5} + \sum_i p_i \sum_m \phi_{mk} Z_m^{0.5} K^{0.5}\right] + \sum_i p_i \phi_{kk} K \quad i,j = 1,2,\ldots T. \tag{1}$$

where i and j are the subscripts for the variable inputs and m and n subscripts for Z which include output and state of technology variable t.[4] Using Shephard's Lemma, demand equation for the i'th factor input X_i can be derived from (Apostolakis, 1990),

$$X_i/Q = \sum_j \alpha_{ij}(p_i/p_j) + \sum_m \beta_{im} Z_m^{0.5} + \sum_m \sum_n \phi_{mn} Z_m^{0.5} Z_n^{0.5}$$
$$+Q^{-0.5}\left[\beta_{ik} K^{0.5} + \sum_m \phi_{mk} Z_m^{0.5} K^{0.5}\right] + \phi_{kk} K \qquad i,j = 1,2,\ldots T. \tag{2}$$

GL function in (Berndt and Wood, 1975) is general, but empirical implementation of such models have suggested that it is convenient to constraint it to a priori long-run constant returns to scale (see Morrison, 1988). Eq. (1) has been revised by setting $\phi_{Qk} = \phi_{mQ} = \beta_{iq} = 0$. The resulting cost equation in which Z only includes Q:

$$G = Q\left[\sum_i \sum_j \alpha_{ij} p_i^{0.5} p_j^{0.5}\right] + Q^{0.5}\left[\sum_i \beta_{ik} p_i K^{0.5}\right] + \sum_i p_i \phi_{kk} K \tag{3}$$

and the corresponding factor demand function as,

$$X_i/Q = \sum_j \alpha_{ij}(p_i/p_j) + Q^{-0.5}(\beta_{ik} K^{0.5}) + Q^{-1}(\phi_{kk} K) \tag{4}$$

We also need to specify the substitution elasticities for the GL variable cost framework defined above. The calculation of short-run elasticities is fairly straight forward,

$$\varepsilon_{ij}^{SR} \equiv \frac{\delta \ln X_i}{\delta \ln p_j} = \frac{\delta X_i}{\delta p_j} \cdot \frac{p_j}{X_i}\bigg|_{k=\bar{k}} \tag{5}$$

In order to compute long-run elasticities, we need first to get an analytical solution of the desired level of capital stocks, K^*. This follows from the fact that the partial derivative of G, the variable cost, with respect to the quasi-factor is the negative of the shadow price of capital $(-\frac{\partial G}{\partial K} = V)$. In the steady state the shadow price of

[4] 1t may also include other exogenous variables such as investment in quasi-fixed factors.

Table 1
Parameter estimates[a]

	Model A	Model B
α_{nn}	6.69×10^{-5}	5.17×10^{-5}
	(2.897)	(2.11)
α_{ee}	-8.7×10^{-5}	-1.5×10^{-5}
	(−1.277)	(−0.3637)
α_{ne}	6.9×10^{-7}	8.8×10^{-7}
	(2.5341)	(2.698)
β_{nt}	0.000401	0.000416
	(10.386)	(9.483)
β_{et}	0.000428	0.000429
	(10.386)	(9.308)
ϕ_{tt}	7.04×10^{-5}	7.15×10^{-5}
	(7.7021)	(7.371)
β_{nk}	−0.0005	−0.0005
	−5.964	(−5.569)
β_{ek}	0.000485	−0.00051
	(5.346)	(−5.395)
ϕ_{tk}	−0.00023	−0.00023
	(−8.759)	(−8.4005)
ϕ_{kk}	0.00048	0.000484
	(7.377)	(6.981)
R_G^2	0.9575	0.9612
R_N^2	0.9848	0.9753
R_E^2	0.7078	0.7212
DW_G	1.602	1.5753
DW_N	1.669	1.685
DW_E	1.791	1.915

[a]*Note*: In Model A price of energy used is from the government published sources. In Model B the energy price aggregate is based on the sub-module (see Appendix A). DW's are the Durbin Watson's statistics. *T*-ratios are in parentheses.

capital is equal to the market rental price of capital p_k. Imposing this equality in the steady state and solving for K^*, we get,

$$K^* = \left[-0.5 \cdot Q^{0.5} \cdot \left(\sum_i \beta_{ik} p_i\right) \Big/ \left(p_k + \sum_i p_i \phi_{kk}\right)\right]^{1/2} \tag{6}$$

The long-run elasticities can now be derived by adding the associated long-run adjustment to the short-run responses by the input demands to an exogenous change:

$$\varepsilon_{ij}^{LR} = \frac{p_j}{X_i}\left[\left.\frac{\delta X_i}{\delta p_j}\right|_{k=\bar{k}} + \frac{\delta X_i}{\delta K} \cdot \frac{\mathrm{d}K}{\mathrm{d}p_j}\right] \tag{7}$$

where $K = K^*$. Other elasticities, such as own-price and cross-price elasticities can also be computed in a similar fashion.

Table 2
Price elasticities[a]

Elasticity	Model A		Model B	
	SR	LR	SR	LR
ε_{nn}	-7.43×10^{-5}	-1.2135	8.68×10^{-5}	-1.2793
	(-2.534)	(17.236)	(-2.699)	(2.699)
ε_{ne}	7.43×10^{-5}	0.000108	8.68×10^{-5}	0.000132
	(2.534)	(7.141)	(2.699)	(5.596)
ε_{nk}	–	1.2137	–	1.2795
		(17.235)		(16.017)
ε_{ee}	-0.24255	-0.24276	-0.31477	-0.31496
	(-2.534)	(-2.5373)	(-2.699)	(-2.701)
ε_{en}	0.24255	0.38798	0.31477	0.45468
	(2.534)	(3.901)	(2.699)	(3.917)
ε_{ek}	–	0.82194	–	0.92872
		(10.422)		(12.362)
ε_{kk}	–	-0.17035	–	-0.17196
		(-8.646)		(-8.052)
ε_{kn}	–	0.17035	–	0.17193
		(8.646)		(8.052)
ε_{ke}	–	4.18×10^{-5}	–	3.39×10^{-5}
		(4.982)		(12.362)

[a] *Note*: In Model A price of energy used is from the government published sources. In Model B the energy price aggregate is based on the sub-module (see Appendix A). SR is the short-run when capital is fixed and LR is for long-run when capital is adjusted to the desired level. *T*-ratios are in parentheses.

3. Data and empirical implementation

Annual time series data for the period 1972–1993 have been used. All data on quantities and prices, except for energy, have been taken from the *Pakistan Economic Survey*. The data on energy components, both quantities and prices have been taken from the *Energy Year Book*. Beside taking energy aggregate prices from the published sources, energy price aggregate was also generated using a Translog Sub-Module (see Appendix A).

The GL model, specified in Chishti and Mahmud (1990) and Iqbal (1986), was estimated for the manufacturing sector of Pakistan. The model assumes one quasi-fixed input, capital K, with two variable inputs labor (N) and energy (E). Since simultaneity is not a problem, the model was estimated using Zellner's iterative estimation procedure. The parameter estimates are presented in Table 1. Most of the parameters are significant at 5% level of significance. R^2 and Durbin Watson statistics are also reported in Table 1, they seem to suggest that the model fits to the data fairly well and there is no serious problem of serial correlation.[5]

All the own price elasticities take the correct sign and significant at 5% level of

[5] Same model was estimated using published energy price aggregate and energy price aggregate generated using the translog sub-module. Results are fairly robust to the choice of the aggregate used.

significance (see Table 2). The own price elasticity of energy is fairly low, both in the short-run and in the long-run. The own price elasticity of labor is low in the short-run but in the long-run when capital stocks adjust to the desired level, the demand for labor is elastic.

Examination of the cross-price elasticities suggests that all inputs are substitutes to each other but the substitution possibilities between energy and non-energy inputs are limited. Therefore the costs of production may rise significantly as a result of energy price shocks. The cross-price elasticities between capital and energy are highly significant. The result indicates that significant energy price shocks do not lead to decrease in capital formation. This is in contrast to the results reported by Chishti and Mahmud (1990), in a full equilibrium framework, in which it was reported that energy price shocks lead to a decrease in capital formation.[6]

A translog sub-module was also estimated to examine inter-fuel substitution possibilities. The methodology and results are provided in Appendix A. The results indicate that there are significant substitution possibilities between electricity and gas. The result shows that an appropriate demand management policy at the time of an external energy shock can be partially absorbed by controlling gas price hikes during this period.[7] Such a policy may not be very effective in the short-run because the cost share of electricity is relatively very high, approximately 70% and the adjustment by the firms to move from a technology that uses electricity to the one which uses gas may not be very easy.

4. Concluding remarks

The purpose of this study was to re-examine the substitution possibilities between energy and non-energy inputs in the manufacturing sector of Pakistan in a framework in which capital is quasi-fixed in the short-run. A partial equilibrium model has been estimated using a GL restricted cost function and treating capital as the only quasi-fixed factor. The results indicate that energy price shocks do not seem to adversely affect investment in the capital goods. This result is in contrast to findings of Chishti and Mahmud (1990), in which energy price shocks do seem to affect capital formation adversely. Furthermore, there are limited substitution possibilities between energy and non-energy inputs and this may suggest that energy price shocks may lead to substantial increases in the cost production of the industries. Finally, an inter-fuel sub-module has also been estimated. The result

[6] There is a controversy about the energy capital complementarity in the literature. Initially Berndt and Wood (1975) found this elasticity for US manufacturing to be -3.2. Most of the inter-country and cross-sectional studies have reported the substitutability between capital and energy while studies using time series data have mostly reported them to be complements. Apostolakis (1990) has reviewed the issue in detail.

[7] Pakistan has large natural resources of gas and most of the electricity production is hydro electricity and therefore is relatively more costly.

suggests that there are significant substitution possibilities between electricity and gas.

Appendix A

A Translog sub-module has also been estimated in order to examine the substitution possibilities between energy components. The sub-module is also used to construct an aggregate energy price index. This price index was later used in the estimation of the model discussed earlier.

Translog cost function corresponding to various energy components may be written as follows:

$$\ln P_E = \ln\phi_o + \sum_i \phi_i \ln P_{Ei} + \sum_i \sum_j \phi_{ij} \ln P_{Ei} \ln P_{Ej} \quad i,j = El.,\ G,\ O \tag{A1}$$

where $E1.$ is for electricity, G is for gas and O is for oil. P_E is the aggregate price index of energy which can also be considered as the cost per unit of energy to the optimizing agents.

The cost-minimizing input demand functions corresponding to Eq. (A1), after imposing homogeneity, symmetry and adding-up restrictions are given as:

$$S_{Ei} = \phi_i + \sum_i \phi_{ij} \ln P_{Ej} \quad i,j = El.,\ G,\ O \tag{A2}$$

Table 3
Parameter estimates of the share equations (Inter-Fuel Sub-Module)[a]

ϕ_e	0.95652
	(48.074)
ϕ_{ee}	0.11648
	(3.241)
ϕ_{eg}	−0.06239
	(−5.391)
ϕ_g	−0.03733
	(−1.258)
ϕ_{gg}	0.07517
	(6.523)
ϕ_o	0.08082
	(2.523)
ϕ_{oo}	0.06686
	(1.202)
ϕ_{eo}	−0.05408
	(−1.256)
ϕ_{go}	−0.01278
	(−0.733)

[a] *Note*: E, electricity; G, Gas; and O, oil. In parentheses are the *t*-ratios.

Table 4
Inter-fuel price elasticities[a]

η_{ee}	−0.06265 (−1.374)	η_{eo}	0.00787 (0.144)
η_{gg}	−0.16016 (−1.405)	η_{oe}	0.08144 (0.144)
η_{oo}	−0.27401 (−0.532)	η_{go}	−0.01922 (−0.148)
η_{eg}	0.05478 (2.960)	η_{og}	−0.03368 (−0.149)
η_{ge}	0.32346 (3.310)		

[a] *Note*: E, electricity; G, Gas; and O, oil. In parentheses are the *t*-ratios.

The parameters of the sub-module are estimated, using Zellner's iterative estimation procedure. The parameters estimates of the energy sub-module are presented in Table 3. Most of the parameters are significant. The own and cross-price elasticities are also computed and are presented in Table 4.

The parameter estimates are substituted back into Eq. (A1) to obtain an aggregate price index for energy which has been used as an instrument in the estimation of the cost function in Eq. (1).

The results of inter-fuel model indicate that cross price elasticities between oil and gas, and oil and electricity are not statistically significant. The cross-price elasticity between electricity and gas are found to be highly significant and show that these two fuels can be substituted for each other (see Table 4). For example, the cross-price elasticity between gas and electricity, η_{ge}. is 0.3235 and therefore an increase of 20% in the relative price of electricity would lead to 6.5% increase in the demand for gas by the manufacturing sector. These results do seem to provide some flexibility in the formulation of demand management policies.

References

Apostolakis, B.E., 1990. Energy-capital substitutability/complementarity: the dichotomy. Energy Econ., January, 48–58.

Berndt, E.R., Wood, D.O., 1975. Technology, prices and derived demand for energy. Rev. Econ. Stat. 57 (3), 254–259.

Chishti, S., Mahmud, F., 1990. The demand for energy in the large-scale manufacturing sector of Pakistan. Energy Econ. 12 (4), 251–254.

Iqbal, M., 1986. Substitution of labour, capital and energy in the manufacturing sector of Pakistan. Energy Econ. 11, 81–95.

Morrison, C., 1988. Quasi-Fixed inputs in U.S. and Japanese manufacturing: a generalized Leontief restricted cost function approach. Rev. Econ. Stat. 70 (2), 275–287.

Pasha, H.A., Ghaus, A., Malik, S., 1990. The differential impact of power load-shedding on industrial units in Pakistan. Pakistan J. Appl. Econ. IX(2), Winter, 117–146.