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INTER-FUEL AND INTRA-FUEL SUBSTITUTION POSSIBILITIES IN THE MANUFACTURING SECTOR OF PAKISTAN

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I. Introduction

For the past two decades or so, the manufacturing sector of Pakistan has been facing an energy crisis in one form or the other. While in the mid-1970s the prices of petroleum products increased significantly, the period of 1980s was marked by severe shortages of electricity supply, which had to be managed by load-shedding. Since energy is an important factor of production,[1] the shortage of energy, especially electricity, in the recent past has been a major hindrance to the growth of the manufacturing sector in Pakistan.[2]

The power shortage crisis of the 1980s was overcome partly by replacing consumption quotas with rationing through prohibitive price increases and partly by successfully attracting direct foreign investment in the power sector. With the introduction of private power producers, though the supply bottlenecks are removed, the price of electricity is expected to rise further in the light of the high procurement price agreed with the independent power producers.

Nevertheless, it was the oil price shocks in the mid-1970s coupled with the movement to protect the environment that aroused interest in energy economics. Following the worldwide trend, several studies have also been conducted in Pakistan to investigate prospects of substituting energy for other factor inputs. All these

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[1] According to the recent issue of Economic Survey, the manufacturing sector consumes almost 16 per cent of petroleum products, 19 per cent of natural gas and almost 30 per cent of the electricity available in the country.

[2] See Pasha, et al., (1989) and Ahmad (1995) on the economic implications of power shortages for the manufacturing sector of Pakistan.

studies [e.g., Ahmad and Idrees (1999), Chishti and Mahmud (1988) and (1991), Khan (1989), and Mahmood (1989) and (1992)], take energy as a single input and, hence, do not consider prospects of substitution within the energy inputs. However, the knowledge of intra-fuel energy substitution is important in a situation when the relative prices of individual energy inputs are changing.

The pricing policy in Pakistan, especially the one relating to subsidies, has recently been subject to significant changes. The IMF guided drive for reducing the budget deficit and making structural adjustments in the economy has resulted in a sharp increase in the prices of energy inputs, especially the prime energy inputs, namely petroleum products and electricity.[3]

In the light of the above background, this paper attempts to explore prospects of substituting one form of energy with another one and with non-energy factor inputs. For this purpose, a Generalized Leontief cost system with four energy inputs (electricity, petroleum products, natural gas and coal/coke) and two non-energy inputs (labor and capital) is estimated. Most of the earlier studies on this subject [Mahmud (1989) and (1992)], Chishti and Mahmud (1991)] have used a Translog cost function while the one by Khan (1989) is based on a three level CES production function, which is not considered a 'flexible' functional form.

The paper is organized as follows. Section II provides details on the specification of technology and substitution elasticities. Data and estimation procedures are discussed in Section III. The empirical results are presented in Section IV. Finally, Section V concludes the paper.

II. The Model

For the study of factor substitution, one can either estimate a production function or any one of the systems of profit, cost or revenue functions, along with the corresponding input demand functions. Given that all the essential information on technology is readily available from the latter with the help of duality relations, there is no specific advantage of assuming an explicit form of production function, and there are many disadvantages. Specifically, only in the case of a restrictive production function can one find a solution for input demand functions under any behavioral assumptions. Furthermore, the system-wide estimation of input demand functions provides more efficient parameter estimates than available from the estimates of a production function. In the system-wise estimation, the cost minimization approach is usually preferred to revenue or profit maximization approaches because

[3] The annual compound growth rate of the producer price index of energy inputs from 1995-96 to 1999-2000 was 12 per cent, against a 6.85 per cent growth in the general producer price index. It is further to be noted that these estimates understate the difference between inflation in energy and non-energy prices because the general indices also include energy prices.

the former provides direct information on various characteristics of production technology, such as the elasticity of substitution, and it does not require any assumption on the product market structure.

In this study, we use a Generalized Leontief cost function, which is a quadratic function of output for the given input prices and a quadratic function of the square roots of input prices for the given output level. The cost function and the associated input demand functions are [see Guilkey et al., (1983)]:

$$C = \sum_{i=1}^{n} \sum_{j=1}^{n} \alpha_{ij} P_j^{1/2} Q + \sum_{i=1}^{n} \alpha_i P_i Q^2 + \sum_{i=1}^{n} \beta_i P_i, \qquad \alpha_{ij} = \alpha_{ji} \tag{1}$$

$$X_i = \sum_{j=1}^{n} \alpha_{ij} P_j^{1/2} P_i^{-1/2} Q + \alpha_i Q^2 + \beta_i \tag{2}$$

where, C, Q and P_i and X_i denote total cost, output, the price of input i and the quantity of input i. It can be seen that the system satisfies the required homogeneity and adding-up properties. Furthermore, parameters appearing in the input demand functions provide complete information on the cost structure and there is no need to estimate the cost function as well.

The prospects of substitution between factor inputs can be studied by estimating elasticities of substitution. Two well-known measures of substitution elasticity are known as Allen partial elasticity and the direct Hicks elasticity. In the two inputs case, Allen partial elasticity of substitution measures the proportional change in the input ratio in response to a small change in the input price ratio. In the general case the elasticity between any two of inputs would depend on the assumptions about the prices and quantities of the other inputs [McFadden (1978)] while changing the particular price ratio. Besides this ambiguity, the Allen partial elasticity does not provide direct information on how the demand for a particular factor input changes in response to its own price or the price of another input. These own or cross price effects can better be measured by the direct Hicks (or compensated) price elasticities of factor demands, which is computed under the assumption that output level and all other prices are held constant. The Hicks elasticities are given by:

$$\varepsilon_{ij} = \frac{\partial X_i \, P_j}{\partial p_j \, X_i} \tag{3}$$

It is easy to verify that for the Generalized Leontief cost functions Hicks elasticities are given by:

$$\varepsilon_{ij} = \frac{P_i^{-1/2} \sum_{j \neq 1} \alpha_{ij} P_j^{1/2} Q}{2X_i} \qquad i = j$$

$$= \frac{\alpha_{ij} P_i^{-1/2} P_j^{1/2} Q}{2X_i} \qquad i \neq j \qquad (4)$$

III. The Data and Estimation Procedure

The cost function is specified for six factor inputs, namely: capital, labor, electricity, natural gas, petroleum products and coke and coal. Unlike some recent studies [e.g., Mahmood (1989), and Burki et al., (1997)], to conserve degrees of freedom raw material is not included among the inputs. This specification can be justified on the ground that raw material is used more or less in a fixed proportion to output.[4]

The Census of Manufacturing Industries (CMI) is the main data source on activities of the manufacturing sector in Pakistan. Most of the data are taken from its sixteen recent publiçations (1969-70, 1970-71, 1975-76 to 1987-88 and 1990-91). Supplementary information is obtained from various issues of Economic Survey and Monthly Statistical Bulletin. To gain degrees of freedom, province level data for Punjab and Sindh where most of the manufacturing firms (more than 80 per cent) are located, are pooled together. This practice has also been adopted successfully in a number of other studies [e.g., Battese and Malik (1987) and Malik, et al., (1989)].

The series of real output is obtained by dividing the value of production by the wholesale price index for the manufacturing sector. Following Christensen and Jorgenson [(1969) and (1970)], the user cost of capital P_K is computed as $P_K = P_M(r+\delta-\pi_M)$, where P_M, r, δ and π_M are, respectively, the price index of capital goods (machinery), rate of interest, capital depreciation rate and the growth rate of P_M. Both for Punjab and Sindh a single series of the price index of machinery is used. Likewise, for both the provinces the interest rate is represented by the single series on the average schedule banks rate on long-term advances to the manufacturing sector. The depreciation rate is calculated by dividing the total depreciation with the value of fixed assets at the beginning of the year. The quantity of capital is calculated by dividing the value of capital by the price index of machinery. Finally, the total user cost of capital is obtained by multiplying the quantity of capital by the user cost.

4 The statistics in Census of Manufacturing Industries show that output and consumption of raw material are growing at almost same rate and the correlation coefficient between the two is 0.82.

The unit labor cost (wage rate) is calculated by dividing the employment cost by average daily persons engaged. Although data on the value and quantity of electricity purchased and the quantity of electricity generated and consumed by the firms is given in the CMI, no information is available on the cost of generation. It is, therefore, assumed that the unit cost of generated electricity is equal to that of purchased electricity. The total cost of electricity consumed is estimated by multiplying the total quantity consumed by the unit cost. The input coke and coal includes coke, coal, charcoal and firewood. The price series for each of these inputs is computed by dividing their costs by the respective quantities. The average price of all these inputs is estimated by constructing a Fisher price index with 1980-81 as a base year. The cost of coke and coal is simply the summation of the costs on coke, coal, charcoal and firewood. Dividing the cost by the price index then yields the quantity index. The same procedure is adopted for the price and cost of petroleum products. The price of gas is calculated by dividing the value of natural gas by its quantity. The total cost is obtained by adding the costs of capital, labor, electricity, petroleum products, natural gas and coke and coal. Finally, the input cost shares are calculated by dividing the value (cost) of each input by the total cost.

Since the input demand functions involve across equation parametric restrictions, the system is estimated by Zellner's efficient method for seemingly unrelated equations. The homotheticity restriction is tested using the likelihood ratio test.

IV. Results

The estimated parameters of the cost function are shown in Table 1. The results show that 12 of the 33 parameters are statistically significant at the 5 per cent level. Since the cost and input demand functions are non-linear, the interpretation of estimated parameters is not straightforward. The output and own price effects on input demands depend on all the variables. Although the cross price effects also depend on own prices, the signs of these cross effects are the same as the signs of the parameters $\alpha_{ij}(i \neq j)$. More definite results on the price responses in input demands will be discussed later with the help of substitution elasticities. At this stage it is sufficient to note that the cross price effects are positive, except for the input pairs, capital and petroleum products, labor and natural gas, labor and coke and coal, and electricity and natural gas.

The Hicks price elasticities estimated at the sample means are reported in Table 2. All the own price elasticities are estimated to be negative as expected. The demand for capital and labor are price inelastic, with only one exception, the demand for energy inputs are price elastic. Furthermore, the own price elasticity estimates for the energy inputs are higher than those for the non-energy inputs. The elasticity estimates for electricity, petroleum products and coke and coal are well above the benchmark value of one, while the elasticity of demand for natural gas is close to one.

TABLE 1

Parameter Estimates for the Generalized Leontief System

Parameter	Estimate	Parameter	Estimate	Parameter	Estimate
β_K	-0.239748 (-1.147)	α_C	-0.000527 (-0.742)	α_{KC}	0.004731 (3.046*)
β_L	0.084825 (4.131*)	α_{KK}	0.536674 (1.470)	α_{LE}	0.014774 (0.513)
β_E	0.041853 (2.000*)	α_{LL}	-0.163763 (-3.172*)	α_{LG}	-0.001650 (-0.133)
β_G	-0.015150 (-1.138)	α_{EE}	-0.273095 (-7.075*)	α_{LP}	0.029068 (3.338*)
β_P	-0.002955 (-0.866)	α_{GG}	0.001445 (0.072)	α_{LC}	-0.003307 (-1.505)
β_C	0.000349 (0.476)	α_{PP}	0.001400 (0.183)	α_{EG}	-0.037532 (-2.462*)
α_K	-0.124206 (-0.885)	α_{CC}	0.000011 (0.008)	α_{EP}	0.000821 (0.103)
α_L	0.023351 (1.744)	α_{KL}	0.166958 (5.268*)	α_{EC}	1.61E-05 (0.008)
α_E	0.093803 (5.229*)	α_{KE}	0.202400 (6.866*)	α_{GP}	0.000571 (0.201)
α_G	-0.006902 (-0.899)	α_{KG}	0.093015 (6.013*)	α_{GC}	0.000317 (0.483)
α_P	-0.004830 (-1.663)	α_{KP}	-0.016950 (-2.639*)	α_{PC}	0.000335 (0.220)

*Significant at the 5 per cent level.

TABLE 2

Hicks Price Elasticities of Factor Demands

Independent variable	Dependent Variable					
	Capital	Labor	Electricity	Natural Gas	Petroleum Products	Coke and Coal
Price of Capital	-0.336	0.639	2.076	1.735	-0.972	1.974
Price of Labor	0.185	-0.310	0.200	-0.040	2.200	-1.820
Price of Electricity	0.178	0.059	-1.438	-0.734	0.049	0.007
Price of Natural Gas	0.083	-0.007	-0.410	-0.924	0.034	0.141
Price of Petroleum Products	-0.014	0.111	0.008	0.011	-1.385	0.140
Price of Coke and Coal	0.006	-0.019	0.001	0.009	0.029	-3.570

These results obviously mean that contrary to the generally held perception, energy demand is reasonably price elastic. The observed increase in the consumption of energy inputs, despite rising energy prices, can be attributed to a number of factors. A possible explanation could be the presence of scale bias found in Idrees (1997) such that the energy intensity rises with the increase in the level of output. Another possibility is the presence of energy using technological progress. In any case the results indicate that the continuous increase in power tariffs and various forms of surcharges on electricity consumption and the price hike in petroleum products, cannot help government raise its revenues in the long run.

The estimates of the cross price elasticities are also given in Table 2. The results show that labor and capital are substitutes for each other. This result is in agreement with the earlier studies [Mahmood (1989) and (1992), and Chishti and Mahmud (1991)] and consistent with the observed changes in factor prices and factor intensities. Over the years the unit cost of labor has grown faster than the rental rate of capital and as a result the capital-labor ratio has increased quite significantly.[5] Thus, as pointed out in some earlier studies [e.g., Kemal (1981)], the factor market distortion in the form of cheaper capital has resulted in the increasing tendency towards capital-intensive techniques of production.

Capital is found to be substitutable with electricity, natural gas and coke and coal, and complementary with petroleum products. The elasticities of substitution between labor and energy inputs have a mixed pattern. The results suggest that labor is complementary with natural gas and coke and coal, while it is substitutable with petroleum products and electricity.

Coming to the inter-fuel elasticities of substitution, electricity and natural gas are found to be complements for each other. This result is consistent with the observation that by and large the two inputs are used for such tasks that complement one another in the completion of the entire production process. Electricity is mostly used to perform mechanical and electric operations while natural gas is more cost effective in heat generation. In the industries like metal, furnace and engineering, natural gas is used for melting the raw material. Electricity in these industries is used to start-up the heating process and to perform other tasks.

Electricity and petroleum products are found to be substitutes for each other but the elasticity of substitution is quite small. Likewise, electricity and coke and coal are also found to be weak substitutes, which appears plausible because the use of coke and coal has primarily been replaced by natural gas and petroleum products while electricity has been used mostly to substitute for labor and capital. The results

[5] The elasticity estimates do not always confirm with the observed changes in input prices and input demands. The reason is that while the partial elasticity of substitution between two inputs is based on the assumption that prices of all other inputs and the level of output are fixed, the observed changes in input ratio are caused by changes in the prices of all the inputs and the output level.

further show that natural gas and petroleum products can be used as substitutes for each other. Finally, natural gas and petroleum products are found to be strong substitutes with coke and coal. This result is strongly supported by the observed decline in the intensity of the use of coke and coal and the increased intensity of natural gas and petroleum products.

It also follows from the result that for any two inputs, the elasticity is greater with respect to the price of input that has a larger cost share. This result is consistent with the expectation that changes in the prices of major inputs should exert greater pressure on firms to reallocate their resources. Thus, for example, the elasticity of labor demand with respect to the capital rental rate is more than three times the elasticity of capital demand with respect to wage rate because the capital rental cost is more than three times the labor cost.

This behavior also explains why the elasticities with respect to the prices of energy inputs are smaller than the elasticities with respect to the capital rental rate and the wage rate. Thus the inter-fuel cross elasticities of substitution are generally quite low. Likewise, the demand for capital and labor are also inelastic with respect to the prices of energy inputs. On the other hand, the demands for energy inputs are quite sensitive to the wage rate and, especially, the capital rental rate.

V. Summary and Conclusions

The main conclusion that emerges from the paper is that energy inputs used in the manufacturing sector of Pakistan are quite sensitive to price changes. The own price elasticities of electricity, petroleum products and coke and coal exceed one, while the own price elasticity of natural gas is close to one. Furthermore, the intra-fuel substitution elasticities are quite large, whereas the inter-fuel substitution elasticities are low. In particular electricity, natural gas and coke and coal appear as close substitutes for capital, while petroleum products are close substitutes for labor. These results suggest that in the long run the manufacturing sector has the capacity of absorbing the rising prices of energy inputs. However, most of the adjustment is likely to take place in terms of increase in capital intensity and at the cost of the reduced rate of labor employment.

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