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# THE ROLE OF CAPITAL - LABOUR AND MAIN ENERGY INPUTS IN THE PERFORMANCE OF GREEK MANUFACTURING SECTOR

By

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## ABSTRACT

In recent years a number of authors have examined the degree if substitutability between labour and capital in Greek industries using time series data for the period 1960-1975. Since, the early seventies, however the traditional inputs, capital-labour, ceased to be the only important factor in production process of Greek manufacturing. Energy, i.e. crude oil, electricity and diesel, emerged as important input. The present study estimates for the first time own and cross price elasticities for capital, labour, crude oil, electricity and diesel, applying a cost function approach to the time series for the period 1970-1990 (JEL D 24 O14).

## 1. Introduction

In recent years a number of papers (Lianos T. 1975, pages 129-141, Kintis A. 1978, pages 27-37, Ioanndes Y. - Caramanis M. 1979, pages 101-110, Panas E. 1986, pages 95-119, Kintis A. and Panas E. 1989, pages 201-212) have been published on the degree of substitution among inputs of production, mainly capital-labour, and the rate of technical efficiency in Greek manufacturing.

During the last two decades however, capital and labour ceased to be the only important inputs of production in the Greek manufacturing. The share of

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the cost of capital as a percentage of the total cost of production dropped in every two digit industry under consideration. More specifically, the share of the cost of capital of production dropped from 64% in 1970 to 58% in 1990, and from 56% to 47% in the same period in industries 22 (tobacco) and 24 (shoes and clothing) respectively, while in industries 32 (oil and coal) and 34 (metallurgy) the capital share dropped even more substantially from 80% (1970) to 39% (1990) and from 74% (1970) to 47% (1990) respectively. On the other hand the problem of labour scarcity that emerged in the late sixties and early seventies (see Lianos T. 1975, page 129-130) —the rate of unemployment in 1972 was 1.8% and the rate of migration was still high— has been eliminated in fact during the same period, 1970-1990, the labour share increased from 34% (1970) to 40% (1990) and from 43% (1970) to 52% (1990) in industries 22 and 24.

At the same time energy emerged as an important input in the production process of Greek industries. The share of the three main sources of energy, crude oil, diesel and electricity increased significantly as a percentage of the total cost in the sector. It is the share of electricity however, which present the largest increase among the energy inputs. Energy's share doubled in industries 22 and 24 between 1970 and 1990, while it increased from 16% to 4% and from 9% to 22% in industries 32 and 34 respectively.

Given those changes in Greek manufacturing and the general changes in the economic circumstances that took place in the last two decades and the fact that the previous studies, even the most recent, used only up to 1975, it becomes obvious that there is a need for the estimation of the own and cross price elasticities of production inputs in Greek manufacturing, including the three energy inputs, crude oil, diesel and electricity.

From a methodological point of view the question of the degree of capital-labour substitutability was examined by the previous studies, excluding Ioannides-Caramanis (Ioannides-Caramanis, 1979, pages 101-110) and Kintis-Panas (Kintis-Panas, 1989, pages 201-212) using the CES production function. However, the CES production function is too restrictive in terms of the implied constraints on the production technology. For example, it is well known that application of the CES function to more than two factors requires the imposition of constraints on substitution possibilities which are too restrictive (see MacFadden L. 1963, page 73). Since one would expect the estimates of elasticities of substitutions to change between any pair of involved inputs than to be constrained, it is desirable to use a flexible functional form which does not impose a priori restriction on the degree of substitution between factors of production alike the CES. The transcendental logarithmic function (known as translog) is one of a class of flexible functional forms and allows the estimation of non-restrictive substitution characteristics for production structures containing many inputs (see Cristensen L. - Lorgenson D, and Lau L. 1973, page 28). Bearing in mind the restrictive assumptions of the CES production function in terms of analysis and hypothesis testing, compared to the transcendental logarithmic function, as well as the role that the different types of energy are expected in the production process, the latter is adopted in the present paper.

The present paper aims to estimate, using time series data for the period 1970-1990, own and cross price elasticities of five factors of production, i.e. capital, labour, electricity, diesel and crude oil, for each of the two digit industries of the Greek sector of manufacturing employing more than ten individuals. The estimates will be obtained using the transcendental logarithmic cost function. In section 2 the model is presented and the restrictions/constraints, as they have been suggested by the economic theory, are presented. Next, in section 3 the adopted model and the theoretical restrictions are related to various industries of the Greek manufacturing sector and the empirical results are presented, while section 4 concludes.

## 2. The Theoretical Model

The specification of the adopted model starts with the assumption that the technology applied in the production process can be described from a twice differentiable production function which relates the flow of output with various factors of production. In algebraic terms it can be expressed as

$$Y = f(X_j) \qquad j = 1,2,3 \ldots \qquad (1)$$

where Y is the output and $X_j$ is the vector of inputs j. It is assumed in (1) that f(Xj) is finite and continues for all non negative Y and X. It is also assumed that monotonicity is valid for f(Xj) and that the production function is strictly convex and that it exhibits constant returns to scale (see Diewert W. 1971, pages 481-483, Hall R. 1973, page 878).

Given the production function (1) and the associated assumptions, the cost function can be derived. According to duality principles (Uzawa H. 1964 pages 216-220, Shephard W. 1970, pages 159-167, Samuelson P. A. 1972, pages 57-89), there is a cost function equivalent to the production function that can represent the technology of production and vice versa.

To start with, it is assumed that the cost function corresponds to the production function can be written as

$$C\ (P.\ Y) = \min P \cdot X = C \tag{2}$$

where C stands for total cost and P is the vector of the prices of inputs. The cost function is considered, similarly to (1), to be twice differentiable, finite and continuous, linear homogeneous in X and P, non decreasing in X and P and concave in P.

The attractiveness of the cost function (2) in econometrics arises from the fact that the prices in this kind of function can be determined exogenously reducing likewise the Collinearity between exogenous variables and from the fact that the presence of serially correlated disturbances in the production functions is eliminated under the cost function specification, which can be described as,

$$C = C\ (PK,\ PL,\ PM,\ PD,\ PE,\ Y) \tag{3}$$

where C is the total cost, Y is the output and $P_K$, PL, PM, PD and PE are the prices of the production factors of capital, labour, crude oil, diesel and electric energy respectively. Function (3) can be represented also by a homothetic transcendental logarithmic form (see Cristensen L. - Jorgenson D. and Lau L. 1973, pages 34-36)

$$\text{lmC} = \ln a_0 + \sum_i \alpha_i \ln P_i + \frac{1}{2} \sum_i \sum_j \gamma_{ij} \ln P_i \ln P_j + \alpha_Y \ln Y \tag{4}$$

where i, j = K, L, M, D and E.

Under conditions of perfect competition the logarithmic differentiation of (4) with respect to input prices Pk, PL, PM, PD and PE yields expressions for the demanded quantity of the corresponding inputs in terms of cost shares (Shephard lemma), i.e.

$$M_i = \frac{\partial \ln C}{\partial \ln P_i} = \frac{P_i X_i}{C} = \alpha_i + \sum_j \gamma_{ij} \ln P_j \tag{5}$$

where Xi is the quantity demanded of the production factor i and Mi is the cost share of the i factor demanded. Also for the cost function (4) to satisfy the adding up criterion, $\Sigma M_i = 1$, and the properties of the neo-classical production theory, the following linear restrictions must be satisfied:

$$\sum_i \alpha_i = 1 \qquad \text{and} \qquad \sum_i \gamma_{ij} = \sum_j \gamma_{ji} = 0 \tag{6}$$

for i,j = K, L, M, D, E.

The restriction (6) implies that the cost function (4) is linear homogeneous in factor prices.

Moreover, the cost function is considered to be "well behaved" when, in addition to the restriction in (3) the hypotheses of monotonicity and concavity are accepted[1]. The symmetry restriction however is not adopted *a priori* in the present study.

The own and cross price elasticities of demand for inputs can be derived by differentiating (5) (see Berndt E. - Wood D. 1976, page 261-262)[2] i.e.

$$E_{ii} = \frac{M_i^2 - M_i + \gamma_{ij}}{M_i} \qquad i = K, L, M, D, E \qquad (7\alpha)$$

$$E_{ij} = \frac{M_i \cdot M_j + \gamma_{ij}}{M_i} \qquad i, j = K, L, M, D, E \quad i{=}j \qquad (7\beta)$$

The statistical implementation of the estimated expression (5) requires the introduction of a disturbance term $u_t$ due to errors in cost minimising behaviour (Berndt E. - Cristensen L. 1973, page 87). Thus the (5) can be written as

$$M^*_i = M_i + U_i \qquad (8)$$

where the term $u_t$ is assumed to be normally distributed[3].

Before proceeding to the estimation of the system of the share equations (8) one equation must be dropped due to the adding —up criterion $\Sigma M_i = 1$. This is based on Bartens (Barten A. 1969 pages 69-71) statement that maximum likelihood estimates are independent of the deleted equation. Bartens statement however is valid under the acceptance of the null hypothesis that

$$E(U_t, U_s) = O \qquad \text{for } t{=}s \qquad (9)$$

Kmenta and Gilbert (Kmenta J. and Gilbert R. 1968, pages 1191-1199) has also shown that the iterative Zellner Efficient Method (IZEF) yields estimates equivalent to those of maximum likelihood. In the case that (9) is rejected the IZEF method is invariant to the omitted equation when additional cross-equations restrictions are imposed (Berndt E. - Savin E. 1975, pages 947-956). More specifically, an autoregressive first order process

$$U_t = \rho\, U_{t-1} + V_t \qquad t = 1 \ldots 21 \qquad (10)$$

is adopted to ensure that the coefficients are the same across share equations.

## 3. Empirical Results

For the reasons presented in section II the method IZEF[4] is adopted for the estimation of (8) using annual data from the Greek manufacturing sector and for the period 1970-1990[5].

Before proceeding to the estimation of the system of the demand functions (8), the equation of capital is deleted due to addin-up of the shares of each factor of production. Therefore the estimated parameters are fourteen instead of nineteen. The remaining five parameters are derived from the a *priori* restriction of linear homogeneity with respect to input prices[6].

Next it is examined whether the estimated function is "well-behaved", in other words if it is increasing in input prices (monotonicity) and if it is concave in input prices. This is equivalent to testing whether the bordered — Hessian matrix is semi-definite negative. The results, based on the calculated bordered Hessian matrix, suggest that only six industries, i.e. 20 (food), 22 (tobacco), 23 (Textiles), 28 (printing), 32 (oil and coal) and 39 (miscellaneous) satisfy the concavity condition. More specifically the concavity condition is satisfied at each observation for the industries 20, 22 and 28. However, the condition failed to be satisfied for the period 1970-73, industry 23, for the period 1970-71, industry 32, and for the period 1970-77 and the years 1984 and 1989, industry 39. The remaining industries under consideration are excluded from the analysis because they fail to satisfy the concavity condition for over half of the observations. Finally it must be mentioned that none of the industries that produce durable satisfy the concavity condition.

For the cost function to be "well behaved" the condition of monotonicity has to be met for the six industries, 20, 22, 23, 28, 32 and 39 which satisfy the concaity condition. The fitted values of cot shares equations are positive for each observation for the whole sample period (1970-1990) for all of the six industries apart from industry 32 where the share of labour is negative for the period 1970-71. It becomes obvious from the above analysis that the cost functions is "well behaved" for industries 20, 22 and 28, while it is partially "well behaved" for industries 23, 32 and 39.

Having identified the cost functions of the industries that are "well behaved" based to the concavity and monotonicity conditions, next the hypothesis of symmetry is examined[7]. The results accept the hypothesis of symmetry for all industries, apart from industry 32, at a 1% statistical level of significance. The presence however of serial correlation in the labour equation (ML), the energy equation (ME), the diesel equation (MD) and in the crude oil equation (MM), as it is indicated by the corresponding estimated values of D.W. values 2.33, 2.081, 0.936, 2.85 may lead to biased standard errors of the estimated regressions of the industry 32, a fact that may well affect the calculated F statistic of this industry and consequently the acceptance or rejection on the hypothesis of symmetry for the specific industry.

The results of the estimated translog cost functions of the industries are presented in table 1 (see Appendix A). The computed values of Pseudo-$R^2$ for each industry is also calculated. The regression results show that the proportion of the variance of $M_i$, i = K, L, E, D, M, explained by the regression model (8) is quite high for all six industries under consideration as it is interpreted from the values of Pseudo-$R^2$. The Pseudo-$R^2$ varies from 0.547 for industry 22 (tobacco) to 0.946 for industry 39 (miscellaneous). On the other hand, the majority o coefficients are statistically different from zero at conventional levels of significance. The independence of residuals of the four equations for each industry is tested regressing the residuals on their lagged values. The regression results indicated that the sequence of residuals, in almost one of the four equation in each industry, is not random. So, we used the autoregressive form (10) to detect the presence o autocorellation.

Next we substituted the estimated coefficients of the translog cost function from table 1 in the forms (7a) and (7b) to derive estimates for own and cross price elasticities for each of the production factors, capital (K), labour (L), electric energy (E), diesel (D) and crude oil (M). The results are presented in table 2 (see Appendix A).

Overall the results, see table 1 in Appendix A, suggest that the estimated own demand price elasticities of each of the factors of production for each of the six industries are statistically significantly different from zero at conventional level of significance and have the expected negative sign. The only results that appear not to be statistically different from zero are those in the beginning of the period especially for industries 22 and 23.

The size of the estimated own demand price elasticities for factors of production varies in the industries under considerations. The common feature of those elasticities across the industries is that the price elasticity of labour is more elastic that the price elasticity of capital, while the price elasticities of the energy inputs are more elastic than the price elasticities of capital and labour in every industry. In general the six industries could be ranked in terms of price elasticities of the inputs as follow:

D>E>M>L>K for industries 20, 22, 23 and 32.
M>E>D>L>K for industry 28 and
E>M>D>L>K for industry 39.

Turning to cross-proce elasticities the results suggest that they are statistically different from zero and positive, apart from the cross price elasticities of diesel and crude oil which appear to be complementary in the production process of the industries 20, 23 and 39.

The cross elasticities of capital-labour and vice-versa are statistically significant from zero and with a positive sign varying around to 0.1 and 0.4. However, two industries, 23 and 32, exhibit negative signs in the beginning of the sample period, i.e. 1970 and 1974, to be followed as expected by positive cross-price elasticities.

The cross price elasticity of electricity and capital has a statistically significant positive sign for all industries, except industry 39 where the estimate is statistically insignificant. The size of the cross elasticity is low varying between 0.1 and 0.3. Electricity and labour also exhibit positive and statistically significant signs for all six of the industries and of higher size than the cross price elasticities of electricity-capital. Electricity and labour appear to be close substitutes in industries 28 and 39. The cross-price elasticity of electricity and labour varies in industry 28 around 0.8 and in industry 39 varies between 0.7 and 1.1 Similarly diesel is a close substitute for labour in industries 20 and 22 and for capital in industries 23, and 32. Finally crude oil substitutes for labour in industries 32 and 39 and for capital in industries 23, 28, 32 and 39. Turning to the cross price elasticities between the energy inputs the results are rather mixed and in most cases the estimates not statistically different from zero. Diesel and crude oil, although substitutes in industry 28, are complements for the industries 20, 23 and 39. Also diesel substitutes for electricity in industry 28.

## 4. Conclusions

The present paper was motivated by the appearance of the significant increase of energy use, i.e. crude oil, diesel and electricity, in Greek manufacturing, and the lack of establishing by the previous authors their effect on the main industries. Also from a methodological point of view, the present paper uses, unlike the previous studies (excluding Caramanis M. and Ioannides Y. 1979, pages 101-110), the transcendental logarithmic cost function applied to more recent data (1970-1990) to capture the radical and frequent changes that the Greek economy and the sector of manufacturing have ben undergoing.

The test on the concavity axion suggest that for more than half of ten industries of Greek manufacturing, including all the durable manufacturing industries, the hypothesis of concavity is not satisfied. The violation of the concavity condition implies that the underlying input demand equations are unstable. However, the data must be generated by stable input demand equations, see Field B.C. and Grebenstein C. 1980, page 209. The observed data in the industries which does not satisfy the concavity condition are simply incompatible with the hypothesis of cost minimisation in the case of a translog cost function specification. Therefore the translog function can not be applied to explain the input relations in these industries. Therefore the analysis must be focused on the industries where the concavity axion is met.

The cross price elasticity of labour and capital is symmetrical in every industry under consideration and varies from 0.07 per cent in the textile industry to around 0.40 per cent in the industries of food and miscellaneous, while in the industries of printing and coal and oil it is around 0.15 per cent. The results suggest that the substitution possibilities between capital and labour in these industries are extremely limited. The own price elasticities of capital are lower than those of labour, as would be expected, given the gestation period required for capital investment. These findings are in line with those of Christopoulos (Christopoulos D. 1995, pages 138-184) for the two -digit manufacturing sector, 1970-1990[9].

Turning to the estimates of the energy inputs it can be clearly inferred that they are close substitutes, especially crude oil and electricity, of labour and to a lesser extend of capital. The level at which electricity substitutes labour in every industry is very high. The reverse, however does not hold. Crude oil also, though at a lower level, substitutes capital in every industry. Finally diesel substitutes labour in the industries of food, tobacco, oil and coal and miscellaneous, and capital in the industries of food and textiles. However, no clear inference can be made about the degree of substitutability between the energy inputs from their cros price elasticities. The results are rather mixed and, in most cases, not statistically different from zero.

Due to the lack of similar studies in the Greek economy no vigorous conclusions can be derived on the robustness of inter-energy substitutability. In addition the use of electricity, diesel and crude oil as energy inputs in the production process make it difficult to compare the findings at the present study with those obtained by other researches for other countries. Among all those researches only two studies contain empirical evidence of diesel electricity substitutability, i.e. Turnovsky et. all (1982) and Considihe (1988)[10]. The first study is referred to the whole manufacturing sector of the Austria economy, 1946-1975 while the second is referred to the economy of USA for the period 1970-1985. The results of those studies provide support for complementarity between diesel and electricity which contrast our findings. However the three studies are not directly comparable because they are applied to different production sectors.

Overall the present study makes clear that, due to the substantial changes that took place in the last two decade in Greek economy and its manufacturing sector, it is very important to examine not only the level of capital —labour substitutability, but also and most importantly capital-labour— energy substitution.

## Appendix A

TABLE 1

Parameter Estimates of Translog Cost Function for the Greek Two Digit Industries with Symmetry Imposed: 1970-1990

**I n d u s t r y**

| | FOOD (20) | TOBACCO (22) | TEXTILES (23) | PRINTING (28) | OIL-coal (32) | MISCH/US (39) |
|---|---|---|---|---|---|---|
| $\gamma_K$ | 0.646 | 0.686 | 0.812 | 0.699 | 0.769 | 0.588 |
| | (0.017) | (0.022) | (0.036) | (0.034) | (0.122) | (0.016) |
| $\gamma_{KK}$ | 0.098 | 0.185 | 0.207 | 0.168 | 0.102 | 0.070 |
| | (0.015) | (0.041) | (0.012) | (0.018) | (0.026) | (0.019) |
| $\gamma_{KL}$ | -0.069 | -0.175 | -0.178 | -0.163 | -0.074 | -0.054 |
| | (0.014) | (0.025) | (0.0011) | (0.018) | (0.008) | (0.019) |
| $\gamma_{KE}$ | -0.012 | -0.006 | -0.022 | -0.005 | -0.009 | -0.011 |
| | (0.002) | (0.032) | (0.004) | (0.001) | (0.003) | (0.002) |
| $\gamma_{KD}$ | -0.002 | -0.001 | 0.000 | -0.000 | -0.002 | -0.002 |
| | (0.001) | (0.000) | (0.001) | (0.000) | (0.006) | (0.001) |

Industry

| | FOOD (20) | TOBACCO (22) | TEXTILES (23) | PRINTING (28) | OIL-coal (32) | MISCH/US (39) |
|---|---|---|---|---|---|---|
| $\gamma_{KM}$ | -0.014 | -0.002 | -0.008 | 0.000 | -0.016 | -0.003 |
| | (0.006) | (0.001) | (0.002) | (0.000) | (0.023) | (0.001) |
| $\gamma_{L}$ | 0.304 | 0.296 | 0.127 | 0.289 | -0.010 | 0.394 |
| | (0.014) | (0.022) | (0.036) | (0.035) | (0.036) | (0.017) |
| $\gamma_{LL}$ | 0.075 | 0.176 | 0.185 | 0.157 | 0.026 | 0.044 |
| | (0.014) | (0.026) | (0.012) | (0.019) | (0.019) | (0.020) |
| $\gamma_{LE}$ | 0.003 | 0.000 | -0.002 | 0.006 | 0.009 | 0.009 |
| | (0.003) | (0.001) | (0.005) | (0.002) | (0.010) | (0.002) |
| $\gamma_{LD}$ | 0.001 | 0.001 | -0.001 | -0.001 | 0.001 | -0.000 |
| | (0.001) | (0.001) | (0.001) | (0.000) | (0.008) | (0.000) |
| $\gamma_{LM}$ | -0.009 | -0.001 | -0.004 | -0.000 | 0.038 | 0.001 |
| | (0.006) | (0.001) | (0.003) | (0.000) | (0.014) | (0.001) |
| $g_{E}$ | 0.021 | 0.012 | 0.046 | 0.009 | 0.024 | 0.013 |
| | (0.002) | (0.001) | (0.008) | (0.003) | (0.011) | (0.001) |
| $\gamma_{EE}$ | 0.004 | 0.006 | 0.021 | -0.002 | 0.001 | -0.001 |
| | (0.004) | (0.001) | (0.005) | (0.002) | (0.007) | (0.003) |
| $\gamma_{ED}$ | -0.001 | 0.000 | 0.001 | 0.001 | -0.001 | 0.001 |
| | (0.001) | (0.000) | (0.001) | (0.000) | (0.004) | (0.001) |
| $\gamma_{EM}$ | 0.007 | 0.001 | 0.001 | 0.000 | -0.001 | 0.002 |
| | (0.002) | (0.001) | (0.002) | (0.000) | (0.005) | (0.001) |
| $\gamma_{D}$ | 0.002 | 0.001 | 0.005 | 0.001 | 0.018 | 0.003 |
| | (0.001) | (0.001) | (0.001) | (0.000) | (0.029) | (0.000) |
| $\gamma_{DD}$ | -0.001 | 0.001 | 0.001 | 0.000 | -0.002 | 0.003 |
| | (0.001) | (0.001) | (0.001) | (0.000) | (0.008) | (0.001) |
| $\gamma_{DM}$ | 0.002 | 0.001 | -0.001 | 0.000 | 0.004 | -0.001 |
| | (0.001) | (0.001) | (0.001) | (0.000) | (0.009) | (0.000) |
| $\gamma_{M}$ | 0.027 | 0.005 | 0.009 | 0.001 | 0.199 | 0.002 |
| | (0.006) | (0.001) | (0.005) | (0.000) | (0.136) | (0.000) |
| $\gamma_{MM}$ | 0.015 | 0.003 | 0.013 | -0.000 | -0.025 | 0.001 |
| | (0.057 | (0.001) | (0.001) | (0.000) | (0.034) | (0.000) |
| Psd $R^2$ | 0.661 | 0.547 | 0.723 | 0.946 | 0.671 | 0.914 |

Note: Figures in parentheses are standard errors.

TABLE 2

Own and Cross Price Elasticities of Greek Manufacturing Industries
(for selected years)

| Elasticity | Year | Industry | | | | | |
|---|---|---|---|---|---|---|---|
| | | FOOD (20) | TOBACCO (22) | PRINTING (28) | TEXTILES (23) | OIL ∞ COAL (32) | MISCH/US (39) |
| $E_{KK}$ | 1970* | -0.20 (0.02) | -0.04 (0.04) | -0.06 (0.03) | 0.03 (0.02) | -0.27 (0.05) | -0.33 (0.04) |
| | 1980 | -0.25 (0.03) | -0.10 (0.04) | -0.17 (0.04) | -0.05 (0.02) | -0.29 (0.05) | -0.35 (0.04) |
| | 1990 | -0.29 (0.03) | -0.10 (0.04) | -0.16 (0.04) | -0.09 (0.03) | -0.33 (0.06) | -0.35 (0.04) |
| $E_{LL}$ | 1970 | -0.45 (0.05) | -0.11 (0.09) | -0.17 (0.06) | 0.25 (0.07) | -0.67 (0.13) | -0.47 (0.05) |
| | 1980 | -0.43 (0.04) | -0.16 (0.06) | -0.18 (0.04) | -0.08 (0.04) | -0.67 (0.10) | -0.45 (0.04) |
| | 1990 | -0.41 (0.04) | -0.16 (0.06) | -0.19 (0.04) | -0.14 (0.03) | -0.65 (0.08) | -0.45 (0.04) |
| $E_{DD}$ | 1970 | -1.16 (0.37) | -0.57 (0.31) | -1.23 (0.19) | -0.74 (0.18) | -1.09 (0.39) | -0.34 (0.18) |
| | 1980 | -1.06 (0.14) | -0.75 (0.18) | -1.11 (0.11) | -0.72 (0.18) | -1.07 (0.34) | -0.40 (0.16) |
| | 1990 | -1.05 (0.13) | -0.68 (0.24) | -1.12 (0.11) | -0.71 (0.19) | -1.06 (0.32) | -0.26 (0.20) |
| $E_{MM}$ | 1970 | -0.41 (0.21) | -0.35 (0.15) | -0.83 (0.16) | -0.21 (0.10) | -0.87 (0.14) | -0.77 (0.14) |
| | 1980 | -0.60 (0.13) | -0.50 (0.12) | -0.81 (0.18) | -0.35 (0.07) | -0.90 (0.16) | -0.78 (0.14) |
| | 1990 | -0.59 (0.14) | -0.34 (0.16) | -0.63 (0.36) | -0.32 (0.08) | -0.87 (0.14) | -0.82 (0.11) |
| $E_{EE}$ | 1970 | -0.80 (0.17) | -0.54 (0.08) | -1.30 (0.15) | -0.51 (0.11) | -0.94 (0.17) | -1.00 (0.11) |
| | 1980 | -0.85 (0.11) | -0.53 (0.09) | -1.45 (0.22) | -0.57 (0.09) | -0.94 (0.17) | -1.00 (0.10) |
| | 1990 | -0.86 (0.10) | -0.50 (0.09) | -1.43 (0.21) | -0.61 (0.08) | -0.93 (0.14) | -0.99 (0.10) |
| $E_{KL}$ | 1970 | 0.20 (0.02) | 0.04 (0.04) | 0.06 (0.03) | -0.06 (0.02) | 0.01 (0.02) | 0.33 (0.04) |
| | 1980 | 0.23 (0.02) | 0.10 (0.04) | 0.16 (0.04) | 0.01 (0.02) | 0.05 (0.02) | 0.35 (0.04) |
| | 1990 | 0.27 (0.03) | 0.10 (0.04) | 0.16 (0.04) | 0.06 (0.02) | 0.08 (0.02) | 0.35 (0.04) |
| $E_{LK}$ | 1970 | 0.42 (0.05) | 0.09 (0.09) | 0.14 (0.06) | -0.28 (0.07) | 0.05 (0.05) | 0.41 (0.04) |
| | 1980 | 0.39 (0.04) | 0.14 (0.06) | 0.16 (0.04) | 0.02 (0.04) | 0.14 (0.04) | 0.39 (0.04) |
| | 1990 | 0.35 (0.03) | 0.14 (0.06) | 0.16 (0.04) | 0.07 (0.03) | 0.14 (0.03) | 0.39 (0.04) |
| $E_{KE}$ | 1970 | 0.002 (0.004) | 0.003 (0.001) | 0.002 (0.002) | 0.02 (0.005) | 0.03 (0.01) | 0.003 (0.004) |
| | 1990 | 0.010 (0.004) | 0.001 (0.050) | 0.007 (0.003) | 0.02 (0.008) | 0.03 (0.01) | 0.006 (0.004) |
| $E_{EK}$ | 1970 | 0.06 (0.11) | 0.17 (0.06) | 0.18 (0.15) | 0.31 (0.08) | 0.34 (0.10) | 0.06 (0.09) |
| | 1980 | 0.21 (0.07) | 0.07 (0.06) | 0.19 (0.08) | 0.24 (0.06) | 0.31 (0.10) | 0.10 (0.06) |
| | 1990 | 0.19 (0.06) | 0.04 (0.06) | 0.21 (0.09) | 0.15 (0.05) | 0.26 (0.10) | 0.11 (0.07) |
| $E_{KD}$ | 1970 | -0.001 (0.001) | -0.001 (0.001) | 0.000 (0.000) | 0.004 (0.001) | 0.03 (0.01) | 0.001 (0.001) |
| | 1980 | 0.001 (0.001) | 0.000 (0.001) | 0.000 (0.000) | 0.004 (0.001) | 0.03 (0.01) | 0.001 (0.001) |
| | 1990 | 0.002 (0.001) | -0.001 (0.001) | 0.000 (0.000) | 0.004 (0.001) | 0.03 (0.01) | 0.00 (0.000) |
| $E_{DK}$ | 1970 | -0.38 (0.37) | -0.50 (0.54) | 0.35 (0.26) | 0.73 (0.13) | 0.66 (0.29) | 0.060 (0.13) |
| | 1980 | 0.19 (0.14) | -0.11 (0.32) | 0.10 (0.29) | 0.59 (0.14) | 0.52 (0.25) | 0.08 (0.12) |
| | 1990 | 0.17 (0.13) | -0.31 (0.41) | -0.25 (0.57) | 0.45 (0.14) | 0.50 (0.23) | -0.02 (0.14) |

| Elasticity | Year | Industry | | | | | |
|---|---|---|---|---|---|---|---|
| | | FOOD (20) | TOBACCO (22) | PRINTING (28) | TEXTILES (23) | OIL ∞ COAL (32) | MISCH/US (39) |
| $E_{KM}$ | 1970 | 0.005 (0.009) | 0.001 (0.002) | 0.001 (0.000) | 0.001 (0.003) | 0.1 (0.04) | 0.002 (0.001) |
| | 1980 | 0.02 (0.01) | 0.002 (0.002) | 0.001 (0.001) | 0.008 (0.004) | 0.18 (0.05) | 0.003 (0.001) |
| | 1990 | 0.01 (0.01) | 0.001 (0.002) | 0.001 (0.001) | 0.003 (0.005) | 0.20 (0.5) | 0.003 (0.001) |
| $E_{MK}$ | 1970 | 0.12 (0.21) | 0.20 (0.23) | 0.85 (0.19) | 0.29 (0.14) | 0.47 (0.10) | 0.37 (0.16) |
| | 1980 | 0.25 (0.13) | 0.21 (0.18) | 0.71 (0.29) | 0.23 (0.11) | 0.44 (0.11) | 0.39 (0.12) |
| | 1990 | 0.18 (0.14) | 0.08 (0.23) | 0.73 (0.28) | 0.08 (0.11) | 0.37 (0.10) | 0.38 (0.13) |
| $E_{LD}$ | 1970 | 0.004 (0.002) | 0.002 (0.002) | -0.002 (0.001) | 0.002 (0.005) | 0.03 (0.06) | 0.003 (0.001) |
| | 1980 | 0.007 (0.002) | 0.002 (0.001) | 0.001 (0.001) | 0.001 (0.003) | 0.03 (0.04) | 0.004 (0.002) |
| 1970 | 0.007 (0.002) | 0.002 (0.001) | 0.001 (0.001) | 0.001 (0.003) | 0.03 (0.04) | 0.004 (0.002) | |
| $E_{DL}$ | 1970 | 0.79 (0.47) | 1.01 (0.71) | -0.80 (0.46) | -0.07 (0.19) | 0.19 (0.37) | 0.34 (0.19) |
| | 1980 | 0.54 (0.18) | 0.82 (0.42) | -0.70 (0.51) | 0.05 (0.20) | 0.23 (0.32) | 0.37 (0.19) |
| | 1990 | 0.57 (0.16) | 0.94 (0.54) | -1.89 (1.00) | 0.16 (0.20) | 0.28 (0.30) | 0.35 (0.24) |
| $E_{LM}$ | 1970 | -0.004 (0.02) | 0.000 (0.004) | 0.001 (0.001) | -0.001 (0.02) | 0.49 (0.10) | 0.01 (0.002) |
| | 1980 | 0.02 (0.02) | 0.003 (0.003) | 0.001 (0.001) | 0.006 (0.009) | 0.41 (0.07) | 0.007 (0.002) |
| | 1990 | 0.02 (0.016) | 0.001 (0.003) | 0.001 (0.001) | 0.009 (0.006) | 0.39 (0.06) | 0.007 (0.002) |
| $E_{ML}$ | 1970 | -0.04 (0.002) | 0.02 (0.28) | 0.11 (0.35) | -0.09 (0.17) | 0.31 (0.06) | 0.80 (0.25 |
| | 1980 | 0.13 (0.14) | 0.18 (0.21) | 0.23 (0.52) | 0.09 (0.13) | 0.37 (0.06) | 0.73 (0.19) |
| | 1990 | 0.17 (0.15) | 0.11 (0.28) | 0.22 (0.50) | 0.21 (0.14) | 0.41 (0.06) | 0.74 (0.20) |
| $E_{LE}$ | 1970 | 0.03 (0.01) | 0.01 (0.003) | 0.03 (0.009) | 0.04 (0.03) | 0.11 (0.07) | 0.05 (0.005) |
| | 1980 | 0.04 (0.01) | 0.013 (0.003) | 0.03 (0.005) | 0.05 (0.02) | 0.10 (0.05) | 0.05 (0.005) |
| | 1990 | 0.04 (0.01) | 0.012 (0.003) | 0.03 (0.005) | 0.06 (0.01) | 0.09 (0.04) | 0.05 (0.005) |
| $E_{EL}$ | 1970 | 0.43 (0.13) | 0.31 (0.08) | 0.97 (0.27) | 0.13 (0.11) | 0.36 (0.24) | 0.82 (0.09) |
| | 1980 | 0.43 (0.08) | 0.41 (0.08) | 0.88 (0.15) | 0.27 (0.09) | 0.41 (0.24) | 0.79 (0.08) |
| | 1990 | 0.48 (0.07) | 0.41 (0.09) | 0.87 (0.15) | 0.40 (0.08) | 0.43 (0.21) | 0.78 (0.07) |
| $E_{DE}$ | 1970 | -0.43 (0.56) | 0.10 (0.49) | 1.08 (0.34) | 0.36 (0.27) | 0.02 (0.18) | 0.20 (0.18) |
| | 1980 | -0.14 (0.21) | 0.06 (0.29) | 1.20 (0.37) | 0.38 (0.28) | 0.02 (0.15) | 0.18 (0.16) |
| | 1990 | -0.12 (0.20) | 0.08 (0.37) | 2.34 (0.73) | 0.40 (0.29) | 0.03 (0.15) | 0.22 (0.20) |
| $E_{ED}$ | 1970 | -0.03 (0.04) | 0.005 (0.026) | 0.07 (0.02) | 0.03 (0.03) | 0.01 (0.10) | 0.03 (0.03) |
| | 1980 | -0.02 (0.03) | 0.006 (0.027) | 0.04 (0.01) | 0.03 (0.02) | 0.01 (0.10) | 0.03 (0.02) |
| | 1990 | -0.02 (0.02) | 0.006 (0.028) | 0.04 (0.01) | 0.03 (0.02) | 0.02 (0.08) | 0.03 (0.02) |
| $E_{DM}$ | 1970 | -1.13 (0.37) | -0.04 (0.35) | 0.20 (0.07) | -0.28 (0.11) | 0.44 (0.43) | -0.27 (0.11) |
| | 1980 | -0.40 (0.14) | -0.02 (0.20) | 0.21 (0.08) | -0.29 (0.11) | 0.39 (0.37) | -0.24 (0.10) |
| | 1990 | -0.36 (0.13) | -0.03 (0.26) | 0.43 (0.15) | -0.31 (0.12) | 0.40 (0.35) | -0.30 (0.13) |
| $E_{MD}$ | 1970 | -0.07 (0.02) | -0.006 (0.05) | 0.20 (0.07) | -0.08 (0.03) | 0.04 (0.04) | -0.32 (0.14) |
| | 1980 | -0.04 (0.01) | -0.004 (0.04) | 0.30 (0.11) | -0.06 (0.03) | 0.05 (0.04) | -0.24 (0.11) |
| | 1990 | -0.04 (0.01) | -0.006 (0.05) | 0.29 (0.10) | -0.7 (0.03) | 0.05 (0.04) | -0.25 (0.11) |

| Elasticity | Year | Industry | | | | | |
|---|---|---|---|---|---|---|---|
| | | FOOD (20) | TOBACCO (22) | PRINTING (28) | TEXTILES (23) | OIL ∞ COAL (32) | MISCH/US (39) |
| $E_{ME}$ | 1970 | 0.26 (0.07) | 0.14 (0.10) | 0.13 (0.23) | 0.10 (0.13) | 0.04 (0.02) | 0.67 (0.18) |
| | 1980 | 0.19 (0.05) | 0.11 (0.08) | 0.20 (0.35) | 0.10 (0.11) | 0.04 (0.02) | 0.52 (0.13) |
| | 1990 | 0.20 (0.05) | 0.14 (0.10) | 0.19 (0.33) | 0.11 (0.11) | 0.05 (0.02) | 0.54 (0.14) |
| $E_{EM}$ | 1970 | 0.33 (0.10) | 0.05 (0.04) | 0.009 (0.016) | 0.03 (0.05) | 0.23 (0.11) | 0.09 (0.0) |
| | 1980 | 0.24 (0.06) | 0.05 (0.04) | 0.005 (0.009) | 0.03 (0.04) | 0.21 (0.11) | 0.08 (0.02) |
| | 1990 | 0.21 (0.05) | 0.06 (004) | 0.005 (0.009) | 0.03 (0.03) | 0.23 (0.10) | 0.08 (0.02) |

Note: Figures in parentheses are standard errors.

* For industries 23, 32 and 39 the first elasticity estimate refers respectively to the years 1975, 1972 and 1978 which are the first years in the sample period for which the monotonicity and concvity are satisfied. For the rest of the industries the first estimate refers to the year 1970.

## Appendix B

1. Capital: The price of capital was calculated as

$$P_K = VA - (W + S) / NFCS$$

where VA is the value added, W and S the wages and salaries respectively and NFCS is the net fixed capital stock (The data on capital stock, for the period 1970-1980, was provided by Kintis (1986). For the period 1981-1990 his approach was followed for the calculation of the data). All figures are expressed at 1970 constant prices. Value added deflators were used to deflate value added and total labour compensation (salaries and wages) variables.

2. Labour: The price of labour (see Lianos T. 1975, pages 135-136), was estimated by

$$P_L = (W^* L) / H$$

where W*L is the wage bill and H is the total number of hours worked by paid workers and employees.

The data on value added and wages and salaries are published in the "Annual Industrial Surveys" (AIS) of the National Statistical Service of Greece (N.S.S.G.) while the deflator one is taken by the "National Accounts" of N.S.S.G.

The wage bill is expressed by means of value added deflators at 1970 constant prices. The necessary data on hours is taken from the "Year Book of Labour Statistics" of the International Labour Office.

3. Diesel - Crude oil Electricity: The prices for the three types of energy were calculated by dividing expenditures by consumption in physical units for each type of energy input. All the data are expressed in 1970 constant prices and are taken from the A.I.S. of N.S.S.G. The deflation has been made by the value added deflators.

4. The annual series for the cost is constructed as follows:

C = value added + total value of three type of energy.

For the period 1978-1979 the N.S.S.G. did not undertake an industrial survey. Therefore for those two years the mean of the series was used to fill the gap.

## Footnotes

1. The monotonicity holds when Mi>0 while the concavity requires the Bordered-Hessian matrix of second partial derivatives with respect to input prices to be semi-definite negative.

2. For the computation of asymptotic standards errors for own and cross price elasticities see Rao (Rao P. 1981, pages 194-195).

3. This hypothesis doesn't affect the results of regressions (see Woodland A.D. 1979, pages 376-380).

4. See Zellner (Zellner A. 1962, pages 348-368, Zellner A. 1963, pages 977-992).

5. For the nature and the structure of the variables see Appendix B.

6. Theil's approach (Theil, H. 1971, pages 338-345) was followed for the estimation of their asymptotic variances.

7. It is considered in the present paper that the symmetry restriction is not incorporated into the cost function as a maintained hypothesis.

8. For the calculation of Pseudo-$R^2$ see, Field B. C. and Grebenstein C. 1980, page 208.

9. It should be noted that Christopoulos estimates of capital-labour substitution involved capital, labour and aggregate energy.

10. These studies are contained in paper of Burniaux's et all (1992).

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