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TRANSLOG PRICE ESTIMATIONS OF SINGAPORE'S MANUFACTURING INDUSTRIES

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I. INTRODUCTION

ECONOMISTS have often used the concept of production and cost functions to depict the structure of production, cost, and technology. Such functions have also been estimated so as to better understand the nature of production and technology for a specific firm, industry, or sector. In the Singapore context, there have so far been two studies in this vein.[1] The earliest, by Chen [6], estimated Cobb-Douglas and CES production functions for the manufacturing sector using annual data from 1960 to 1970. Toh [20] estimated CES production functions for individual manufacturing industries using annual data from 1963 to 1981. Both of these studies attempted to determine the rate of technical change from the estimated values of the parameters. Technical change was defined to be Hicks-neutral in the case of Chen and factor-augmenting in the case of Toh. Both of these studies also assumed that value added is a function of capital, labor, and time, an assumption which may not be valid in the Singapore context.[2] The goal of this paper is to contribute further to the understanding of the nature of production and technology in Singapore manufacturing industries. The concept of total factor productivity growth (TFPG) is used, where TFPG is the growth in efficiency in the use of all inputs and is computed as the residual of the growth in output less a weighted sum of the growth in inputs.[3] Unlike the previous papers, the TFPG for Singapore's manufacturing industries for 1970–79 was first calculated using translog indices of output, capital, labor, energy, and

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1 In terms of chronological order, the first study was by Chen [6]. This paper is adapted from Tsao [21], her Ph.D. dissertation written at Harvard University. The original version of this paper therefore predates Toh [20], which is a chapter from his Ph.D. thesis.

2 The validity of the value-added function requires certain conditions to be satisfied. Berndt and Wood [2] give the cases in which it is valid to analyze substitution possibilities between capital K and labor L while ignoring energy E, and non-energy intermediate inputs X. Any one of the following assumptions are sufficient: (a) the quantity ratios E/Q and X/Q, where Q is gross output, always move in fixed proportions (that is, are perfectly correlated); (b) the prices of energy, non-energy intermediate inputs and output always move in fixed proportions; or (c) the inputs K and L are weakly separable from E and X.

3 A number of studies on the measurement of TFPG at the industry level have been carried out. For developing countries, some of these are [15] [18].

non-energy intermediate inputs [21] [22]. It was found that TFPG was, on the whole, very low. The next step was to utilize this data base for empirical estimation, which is the subject of this paper. The production structure assumed in this paper is the more general one where gross output is a function of capital, labor, energy, and non-energy intermediate inputs and time. The functional form used, the translog, is a flexible functional form which allows for the testing of hypotheses which would not be possible with more restricted functional forms such as the Cobb-Douglas. Furthermore, TFPG is specified as a function of the prices of inputs and time, thus enabling a more detailed examination of the nature of TFPG. This paper therefore has three objectives. The first objective is to examine the characteristics of TFPG. Hypotheses regarding whether TFPG is Hicks-neutral will be tested, and the pattern of TFPG in terms of its dependence on the inputs will be examined. The second objective is to test several hypotheses regarding the production structure, such as the validity of the value-added specification of production. The third objective is to examine whether the inputs are complements or substitutes. The organization of the rest of the paper is as follows: Section II describes the theoretical framework and methodology; Section III discusses the hypotheses to be tested and the results; the dependence of TFPG on input prices is analyzed in Section IV; the relationship among inputs is investigated in Section V; and the conclusion is presented in Section VI.

II. THEORETICAL FRAMEWORK

The output Q of each manufacturing industry i is a function of four inputs—non-energy intermediate input X, capital input K, labor input L, and energy input E—and time T:

$$Q^i = F^i(X_i, K_i, L_i, E_i, T), \quad (i=1, 2, \cdots, n). \tag{1}$$

The dual to equation (1) is a cost function which specifies total cost C as a function of the prices of the four inputs mentioned above, $p_X{}^i$, $p_K{}^i$, $p_L{}^i$, $p_E{}^i$ respectively, time and output:[4]

$$C^i = G^i(p_X{}^i, p_K{}^i, p_L{}^i, p_E{}^i, T, Q^i), \quad (i=1, 2, \cdots, n). \tag{2}$$

The imposition of homogeneity of degree one translates the cost function to a unit cost or price function, where $p_Q{}^i$ is the price of output:[5]

$$p_Q{}^i = f^i(p_X{}^i, p_K{}^i, p_L{}^i, p_E{}^i, T), \quad (i=1, 2, \cdots, n). \tag{3}$$

[4] For a discussion of duality which is the most relevant to this paper, see [10] [11] [12].

[5] In the absence of an independent estimate of the degree of returns to scale, the assumption of homogeneity of degree one is needed in order that changes in output not due to corresponding changes in input can be attributed to TFPG. This assumption is also needed in order for the value shares of the four inputs to sum to unity and for the value share of capital to be derived. The conclusion includes a brief discussion of the bias which would result if this assumption were invalid.

For the purposes of econometric modelling, a translog price function is specified as follows:[6]

$$\ln p_Q{}^i = \alpha_0{}^i + \sum_j \alpha_j{}^i \ln p_j{}^i + \alpha_T{}^i \cdot T + \frac{1}{2}\sum_j\sum_k \beta_{jk}{}^i \ln p_j{}^i \ln p_k{}^i + \sum_j \beta_{jT}{}^i \ln p_j{}^i \cdot T + \frac{1}{2}\beta_{TT}{}^i \cdot T^2,$$
$$(j,\ k = X,\ K,\ L,\ E;\ i = 1,\ 2,\ \cdots,\ n). \qquad (4)$$

The conditions for symmetry and homegeneity of degree one in the input prices are that

$$\sum_j \alpha_j{}^i = 1,$$
$$\sum_k \beta_{jk}{}^i = 0, \qquad (5)$$
$$\sum_j \beta_{jT}{}^i = 0,$$
$$\beta_{jk}{}^i = \beta_{kj}{}^i, \quad j \neq k, \quad (j,\ k = X,\ K,\ L,\ E;\ i = 1,\ 2,\ \cdots,\ n).$$

In producer equilibrium and constant returns to scale, the translog price function can also be expressed in terms of the value shares of the four inputs, $v_j{}^i$ and the negative of TFPG, $-v_T{}^i$:

$$v_j{}^i = \alpha_j{}^i + \sum_k \beta_{jk}{}^i \ln p_k{}^i + \beta_{jT}{}^i \cdot T,$$
$$-v_T{}^i = \alpha_T{}^i + \sum_j \beta_{jT}{}^i \ln p_j{}^i + \beta_{TT}{}^i \cdot T, \quad (j,\ k = X,\ K,\ L,\ E;\ i = 1,\ 2,\ \cdots,\ n). \qquad (6)$$

In other words, TFPG is dependent on a constant term, on time and on the logarithms of prices (prices for short). The parameters $\beta_{jT}{}^i$ are of special interest in this context for they denote the responsiveness of TFPG to each of the four input prices:

$$\frac{\partial v_T{}^i}{\partial \ln p_j{}^i} = -\beta_{jT}{}^i, \quad (j = X,\ K,\ L,\ E;\ i = 1,\ 2,\ \cdots,\ n). \qquad (7)$$

If for example, $\beta_{ET}{}^i$ is positive, then TFPG falls as the price of energy increases. TFPG is said to be using in input j if $\beta_{jT}{}^i$ is positive, and TFPG to be saving in input j if $\beta_{jT}{}^i$ is negative [14].

For the purposes of estimation, one of the value share equations in (6) has to be dropped because of the constant returns to scale assumption. The value share equation for energy is therefore omitted. A stochastic error term is added to each of the other three equations. The error terms are assumed to have expectation zero and a positive definite covariance matrix, and to be uncorrelated over time.

Since the translog index of TFPG is an average over two consecutive years,

[6] The translog price function is discussed by Christensen, Jorgenson, and Lau [7] [8], Berndt and Christensen [1], and Gollop and Jorgenson [13]. The methodology used in this paper is adapted from [14].

the average value shares of the three inputs and the average TFPG are estimated as the functions of the average of the input prices and time. This implies that the error terms are now correlated over time so that each of the four equations has to be transformed appropriately to eliminate the autocorrelation caused by the averaging process.[7] The four equations which are estimated simultaneously are the transformed versions of the three value share equations and $-v_T^i$:

$$\begin{aligned}
\overline{v_X^i} &= \alpha_X^i + \beta_{XX}^i \overline{\ln p_X^i} + \beta_{XK}^i \overline{\ln p_K^i} + \beta_{XL} \overline{\ln p_L^i} + \beta_{XE}^i \overline{\ln p_E^i} + \beta_{XT}^i \cdot \overline{T} + \overline{\epsilon_X^i}, \\
\overline{v_K^i} &= \alpha_K^i + \beta_{XK}^i \overline{\ln p_X^i} + \beta_{KK}^i \overline{\ln p_K^i} + \beta_{KL}^i \overline{\ln p_L^i} + \beta_{KE}^i \overline{\ln p_E^i} + \beta_{KT}^i \cdot \overline{T} + \overline{\epsilon_K^i}, \\
\overline{v_L^i} &= \alpha_L^i + \beta_{XL}^i \overline{\ln p_X^i} + \beta_{KL}^i \overline{\ln p_K^i} + \beta_{LL}^i \overline{\ln p_L^i} + \beta_{LE}^i \overline{\ln p_E^i} + \beta_{LT}^i \cdot \overline{T} + \overline{\epsilon_L^i}, \\
-\overline{v_T^i} &= \alpha_T^i + \beta_{XT}^i \overline{\ln p_X^i} + \beta_{KT}^i \overline{\ln p_K^i} + \beta_{LT}^i \overline{\ln p_L^i} + \beta_{ET}^i \overline{\ln p_E^i} + \beta_{TT}^i \cdot \overline{T} + \overline{\varepsilon_T^i}, \\
& \qquad (i = 1, 2, \cdots, n), \quad (8)
\end{aligned}$$

where a bar over a variable denotes the average over time periods T and $(T-1)$.

The data used in the estimations is part of a data base constructed for twenty-eight manufacturing industries in Singapore for 1970–79 from annual censuses of manufacturing. The construction of the translog indices of real capital, labor, energy, and non-energy intermediate inputs is described in Tsao [21] [22, pp. 35–37]. In particular, the perpetual inventory method was mainly used to compute the capital input series from data on net fixed assets and capital expenditure. The input price indices were then derived from these translog quantity indices. They were computed as the ratio of the value of the input to the quantity index for each input and normalized at the base year, 1974. Real gross output series were available at the industry level. The output price series were obtained as the value of gross output divided by real gross output, normalized at 1974.

III. TESTING OF HYPOTHESES

The theoretical framework leading to the formulation of the four equations in (8) above enables certain hypotheses to be tested in order to investigate the nature of TFPG and the validity of certain specifications of the production structure.

A. *Hypotheses*

The hypotheses to be tested fall into two main groups, regarding (a) TFPG and (b) specification of the production structure, namely, the existence of a price of value-added function and the separability of the prices of capital and energy.

1. *TFPG*

From the equation for the negative of TFPG in equations (8), it can be seen that TFPG (i) has a trend term represented by α_T^i; (ii) depends on time through β_{TT}^i; and (iii) depends on the input prices through β_{XT}^i, β_{KT}^i, β_{LT}^i, and β_{ET}^i. The following three hypotheses can be formulated:

[7] See [14] for details of the transformation procedure for two value-added equations (in a three-input model) and the negative of TFPG. Also see [21] for the details of the procedure used in this paper.

$$
\begin{array}{ll}
(1) & \alpha_T{}^i = 0, \\
(2) & \beta_{TT}{}^i = 0, \\
(3) & \beta_{XT}{}^i = \beta_{KT}{}^i = \beta_{LT}{}^i = 0, \\
(3a) & \alpha_T{}^i = \beta_{TT}{}^i = 0, \quad (i = 1, 2, \cdots, n).
\end{array} \tag{9}
$$

Hypothesis (1) postulates that there is no constant term in TFPG, that TFPG depends entirely on input prices and/or time, apart from random errors. Hypothesis (2) postulates that TFPG does not change with time and that there is no change in TFPG due to time alone. Hypothesis (3) states that TFPG is independent of all four input prices. If this is so, then TFPG can be said to be Hicks-neutral.[8] If this hypothesis is not rejected, then hypothesis (3a) is tested, which together with hypothesis (3) states that TFPG is entirely random, and depends on neither input prices nor time and does not have a constant term.

2. *Production structure*

A common assumption made in empirical work is that it is valid to use value added as a function of capital, labor, and time. The dual to this specification is a price of value-added function where the price of value added is a function of the prices of capital and labor, and of time:

$$g^i = g^i(p_K{}^i, p_L{}^i, T), \quad (i = 1, 2, \cdots, n). \tag{10}$$

The price function then becomes weakly separable as follows:

$$p_Q{}^i = p^i[p_X{}^i, p_E{}^i, g^i(p_K{}^i, p_L{}^i, T)], \quad (i = 1, 2, \cdots, n). \tag{11}$$

The testing for the existence of a price of value-added function can be formulated in terms of two jointly necessary and sufficient conditions [14]:

$$
\begin{array}{ll}
(4) & \beta_{XK}{}^i = \rho_X{}^i \alpha_K{}^i, \; \beta_{XL}{}^i = \rho_X{}^i \alpha_L{}^i, \; \beta_{XT}{}^i = \rho_X{}^i \alpha_T{}^i, \\
 & \beta_{EK}{}^i = \rho_E{}^i \alpha_K{}^i, \; \beta_{EL}{}^i = \rho_E{}^i \alpha_L{}^i, \; \beta_{ET}{}^i = \rho_E{}^i \alpha_T{}^i, \\
(4a) & \rho_X{}^i = \rho_E{}^i = 0, \\
(5) & \dfrac{v_K{}^i}{v_L{}^i} = \dfrac{\beta_{XK}{}^i}{\beta_{XL}{}^i} = \dfrac{\beta_{KE}{}^i}{\beta_{LE}{}^i}; \quad \dfrac{v_K{}^i}{-v_T{}^i} = \dfrac{\beta_{XK}{}^i}{\beta_{XT}{}^i} = \dfrac{\beta_{KE}{}^i}{\beta_{ET}{}^i}, \\
 & \qquad (i = 1, 2 \cdots, n).
\end{array} \tag{12}
$$

Hypothesis (4a) is to be tested conditional on the non-rejection of hypothesis (4). Both hypotheses (4/4a) and (5) have different implications for the specification of the price of value-added function [21].

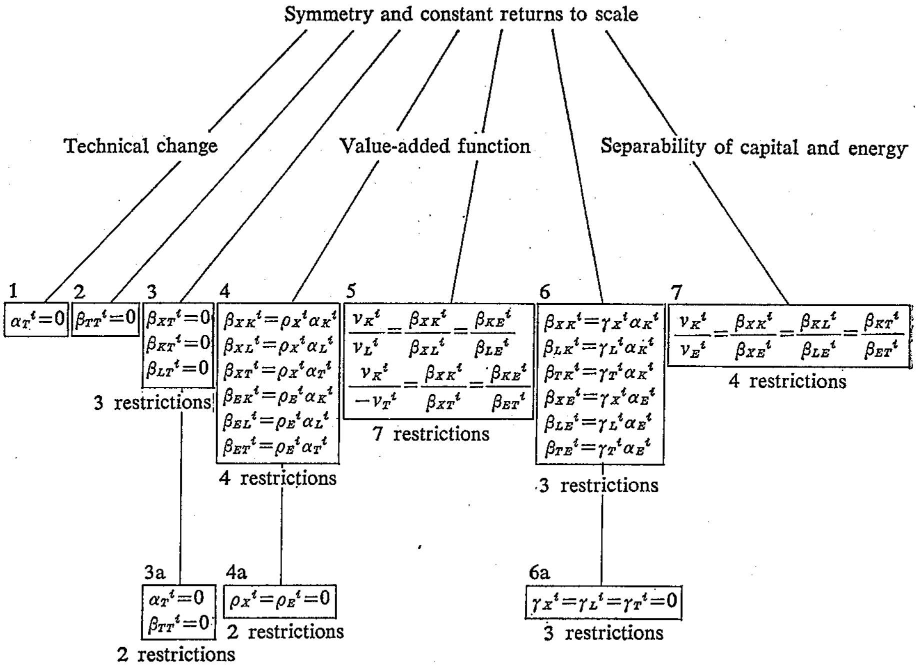
We would also like to test for the existence of a function of the prices of capital and energy, following Berndt and Wood [2]:

$$H^i = H^i(p_K{}^i, p_E{}^i), \quad (i = 1, 2, \cdots, n). \tag{13}$$

The price function then becomes:

[8] This is equivalent to the independence of TFPG with respect to the corresponding inputs. See for example [3] [13].

Fig. 1. Tests of Hypotheses



$$p_Q^i=J^i[p_X^i,\ p_L^i,\ T,\ H^i(p_K^i,\ p_E^i)],\quad (i=1,\ 2,\ \cdots,\ n). \tag{14}$$

In other words, the prices of capital and energy can be considered as a composite entity in empirical work, which is a more detailed version of hypothesis (2). The exact conditions are analogous to those in hypotheses (4), (4a), and (5):

$$\begin{aligned} &(6)\quad \beta_{XK}^i=\gamma_X^i\alpha_K^i,\ \beta_{LK}^i=\gamma_L^i\alpha_K^i,\ \beta_{TK}^i=\gamma_T^i\alpha_K^i,\\ &\qquad\ \beta_{XE}^i=\gamma_X^i\alpha_E^i,\ \beta_{LE}^i=\gamma_L^i\alpha_E^i,\ \beta_{TE}^i=\gamma_T^i\alpha_E^i,\\ &(6a)\quad \gamma_X^i=\gamma_L^i=\gamma_T^i=0,\\ &(7)\quad \frac{v_K^i}{v_E^i}=\frac{\beta_{XK}^i}{\beta_{XE}^i}=\frac{\beta_{KL}^i}{\beta_{LE}^i}=\frac{\beta_{KT}^i}{\beta_{ET}^i},\quad (i=1,\ 2,\ \cdots,\ n). \end{aligned} \tag{15}$$

The testing procedure is as follows: There are ten tests in all. The standard normal (test) is used for the single-parameter tests of hypotheses (1) and (2), while the likelihood ratio test is used for the other eight hypotheses. For the latter set of tests, the equation system is estimated with and without the specified restrictions and the log-likelihood ratios obtained. The likelihood ratio test states that minus twice the difference of the log-likelihood ratios is asymptotically

TABLE I

NUMBER OF INDUSTRIES FOR WHICH THE HYPOTHESES ARE REJECTED/NOT REJECTED

	Rejected	Not Rejected
Hypothesis 1	28	0
Hypothesis 2	27	1
Hypothesis 3	22	6
Hypothesis 3a	1	5
Hypothesis 4	13	15
Hypothesis 4a	11	4
Hypothesis 5	25	3
Hypothesis 6	17	11
Hypothesis 6a	7	4
Hypothesis 7	25	3

distributed as X_n^2 where n is the number of additional restrictions imposed by the null hypothesis. Figure 1 summarizes the hypotheses to be tested and states the number of restrictions for each.[9] These ten tests are carried out jointly. Setting the overall level of significance at 0.05, the level of significance of each test is therefore 0.005.[10]

The alternative hypothesis against which the above hypotheses are tested [except for the nested tests (3a) and (6a)] is the translog price function with constant returns to scale and symmetry. There are fourteen parameters to be estimated for this model. The sample consists of thirty-six observations for each of the twenty-eight industries, since there are nine observations over time and four equations per industry. The estimation technique used throughout is multivariate regression, which gives maximum likelihood estimates on convergence.

B. *Results*

1. *TFPG*

As can be seen from Table I and Appendix Table I, hypothesis (1), that there is no constant term for TFPG, is not rejected for all industries. Similarly hypothesis (2), that TFPG does not vary with time, is not rejected for twenty-seven industries. The hypothesis of Hicks-neutrality is rejected for twenty-two industries. For the six for which this could not be rejected, the nested test (3a) is then carried out. The results show that for five industries the hypothesis that TFPG is entirely random could not be rejected. For twenty-two industries, therefore, TFPG is shown to be dependent on input prices and is not Hicks-neutral. The nature of this dependence will be examined in the next section.

9 A more detailed description of the derivation of the number of restrictions can be found in [21].

10 In other words, the upper bound of the probability of falsely rejecting any or all of these hypotheses is 0.05. For examples of such testing see [8] [9].

2. *Production structure*

Hypotheses (4) and (4a) could not be rejected for only four industries. Similarly hypothesis (5) could not be rejected for three industries. This implies that for the majority of industries a price of value-added function does not exist. Duality implies that there is little evidence for the existence of value-added functions for manufacturing industries in Singapore.

Hypotheses (6), (6a), and (7), to test for the separability of the prices of capital and energy, are also rejected for a large number of industries, twenty-four for (6/6a) and twenty-five for (7). This implies that there is no evidence for the separability of capital and energy from the other inputs and time for the majority of industries.

To summarize, TFPG is found not to be Hicks-neutral in the majority of industries. Similarly, there is little evidence for the validity of the use of value-added functions or of the separability of capital and energy in Singapore manufacturing industries.

IV. TFPG AND INPUT PRICES

The rejection of Hicks-neutrality for twenty-two industries implies that for these industries TFPG is dependent on the prices of inputs. This section describes the estimation of the model so as to obtain estimates of the parameters denoting the relationship between TFPG and input prices.

The neoclassical theory of production gives three sets of restrictions which have to be satisfied for producer equilibrium. First, the price function has to be increasing in all four input prices, implying that the value shares are non-negative:

$$v_X^i \geq 0,\ v_K^i \geq 0,\ v_L^i \geq 0,\ v_E^i \geq 0, \quad (i=1, 2, \cdots, n). \tag{16}$$

This condition is satisfied throughout the sample.

The second restriction is that of constant returns to scale:

$$v_X^i + v_K^i + v_L^i + v_E^i = 1, \quad (i=1, 2, \cdots, n). \tag{17}$$

The third restriction, which is necessary for producer equilibrium, is that the price function is concave, or that the Hessian matrix of second-order partial derivatives is negative semi-definite. The necessary and sufficient condition for global concavity is that the matrix of share elasticities is negative semi-definite [14] [21]. The matrix of share elasticities can be represented by its Cholesky factorization as follows:

$$\begin{vmatrix} \beta_{XX}^i & \beta_{XK}^i & \beta_{XL}^i & \beta_{XE}^i \\ \beta_{XK}^i & \beta_{KK}^i & \beta_{KL}^i & \beta_{KE}^i \\ \beta_{XL}^i & \beta_{KL}^i & \beta_{LL}^i & \beta_{LE}^i \\ \beta_{XE}^i & \beta_{KE}^i & \beta_{LE}^i & \beta_{EE}^i \end{vmatrix}$$

$$=\begin{vmatrix} 1 & 0 & 0 & 0 \\ \lambda_{21}^i & 1 & 0 & 0 \\ \lambda_{31}^i & \lambda_{32}^i & 1 & 0 \\ \lambda_{41}^i & \lambda_{42}^i & \lambda_{43}^i & 1 \end{vmatrix} \begin{vmatrix} \delta_1^i & 0 & 0 & 0 \\ 0 & \delta_2^i & 0 & 0 \\ 0 & 0 & \delta_3^i & 0 \\ 0 & 0 & 0 & \delta_4^i \end{vmatrix} \begin{vmatrix} 1 & \lambda_{21}^i & \lambda_{31}^i & \lambda_{41}^i \\ 0 & 1 & \lambda_{32}^i & \lambda_{42}^i \\ 0 & 0 & 1 & \lambda_{43}^i \\ 0 & 0 & 0 & 1 \end{vmatrix}$$

$$=\begin{vmatrix} \delta_1^i & \delta_1^i\lambda_{21}^i & \delta_1^i\lambda_{31}^i & \delta_1^i\lambda_{41}^i \\ \delta_1^i\lambda_{21}^i & \delta_1^i\lambda_{21}^{i2}+\delta_2^i & \delta_1^i\lambda_{21}^i\lambda_{31}^i+\delta_2^i\lambda_{32}^i & \delta_1^i\lambda_{21}^i\lambda_{41}^i+\delta_2^i\lambda_{42}^i \\ \delta_1^i\lambda_{31}^i & \delta_1^i\lambda_{21}^i\lambda_{31}^i+\delta_2^i\lambda_{32}^i & \delta_1^i\lambda_{31}^{i2}+\delta_2^i\lambda_{32}^{i2}+\delta_3^i & \delta_1^i\lambda_{31}^i\lambda_{41}^i+\delta_2^i\lambda_{32}^i\lambda_{42}^i+\delta_3^i\lambda_{43}^i \\ \delta_1^i\lambda_{41}^i & \delta_1^i\lambda_{21}^i\lambda_{41}^i+\delta_2^i\lambda_{42}^i & \delta_1^i\lambda_{31}^i\lambda_{41}^i+\delta_2^i\lambda_{32}^i\lambda_{42}^i+\delta_3^i\lambda_{43}^i & \delta_1^i\lambda_{41}^{i2}+\delta_2^i\lambda_{42}^{i2}+\delta_3^i\lambda_{43}^{i2}+\delta_4^i \end{vmatrix}, \quad (i=1, 2, \cdots, n). \tag{18}$$

Under the conditions of symmetry and constant returns to scale the parameters of the Cholesky factorization satisfy the following conditions:

$$\begin{aligned} 1+\lambda_{21}^i+\lambda_{31}^i+\lambda_{41}^i&=0, \\ 1+\lambda_{32}^i+\lambda_{42}^i&=0, \\ 1+\lambda_{43}^i&=0, \\ \delta_4^i&=0, \quad (i=1, 2, \cdots, n). \end{aligned} \tag{19}$$

Under these conditions, there is a one-to-one transformation between the β^i's and the parameters of the Cholesky factorization. The matrix of share elasticities is negative semi-definite if and only if the diagonal elements δ_1^i, δ_2^i, and δ_3^i are non-positive. Global concavity can therefore be imposed by restricting δ_1^i, δ_2^i, and δ_3^i to be non-positive.

The estimation is therefore carried out in terms of the parameters of the Cholesky factorization, δ_1^i, δ_2^i, δ_3^i, λ_{21}^i, λ_{31}^i, λ_{32}^i, and the remaining parameters of the price function, α_X^i, α_K^i, α_L^i, α_T^i, β_{XT}^i, β_{KT}^i, β_{LT}^i, and β_{ET}^i. In order to satisfy the non-positive restriction, combinations of the diagonal elements δ_1^i, δ_2^i, and δ_3^i are in turn set equal to zero. There are seven possible cases: (i) $\delta_1^i=0$; (ii) $\delta_2^i=0$; (iii) $\delta_3^i=0$; (iv) $\delta_1^i=\delta_2^i=0$; (v) $\delta_1^i=\delta_3^i=0$; (vi) $\delta_2^i=\delta_3^i=0$; and (vii) $\delta_1^i=\delta_2^i=\delta_3^i=0$. That case for which the non-positive constraints are satisfied and for which the log-likelihood function is highest is chosen. The parameter estimates of the translog price function for each industry are then derived. These, together with their standard errors, are shown in Appendix Table II.

The focus of this section is on the relationship of TFPG with the input prices, or on the parameters β_{XT}^i, β_{KT}^i, β_{LT}^i, and β_{ET}^i. Recall from equation (7) that these parameters signify the response of TFPG to each input price. A positive estimate implies that TFPG decreases as the input price increases. If, for example, β_{LT}^i is positive, then TFPG is said to be labor-using in industry i. Conversely, if β_{ET}^i is negative, then TFPG increases with the price of energy. TFPG is then said to be energy-saving.

TABLE II

RELATIONSHIP BETWEEN TFGP AND INPUT PRICES

(i)	Materials saving, capital using, labor saving, energy using	
	4 industries:	textiles
		chemical products
		concrete products
		iron and steel
(ii)	Materials using, capital using, labor saving, energy using	
	4 industries:	timber products
		pottery and glass products
		nonmetallic mineral products
		transport equipment
(iii)	Materials saving, capital using, labor using, energy using	
	4 industries:	food
		wearing apparel
		fabricated metal products
		industrial machinery
(iv)	Materials using, capital saving, labor using, energy using	
	3 industries:	tobacco products
		rubber products
		plastic products
(v)	Materials using, capital saving, labor saving, energy saving	
	2 industries:	beverages
		electrical machinery
(vi)	Materials using, capital saving, labor saving, energy using	
	2 industries:	furniture and fixtures
		industrial chemicals
(vii)	Materials saving, capital using, labor using, energy saving	
	1 industry:	leather products
(viii)	Materials saving, capital saving, labor saving, energy using	
	1 industry:	structural clay products
(ix)	Materials saving, capital using, labor saving, energy saving	
	1 industry:	cement

Note: The definitions of the terms used are as follows: "using" in input j: $\beta_{jT}>0$; "saving" in input j: $\beta_{jT}<0$, $j=X, K, L, E$.

Table II presents the dependence of TFPG on the input prices for the twenty-two industries for which Hicks-neutrality has been rejected. There is no single predominant pattern of variation of TFPG with respect to all four inputs. The variation with respect to individual inputs is however, more clear-cut. TFPG is capital-using in fourteen industries, labor-saving in fourteen industries, and energy-using in eighteen industries. The industries are about equally divided between materials-using and materials-saving TFPG.[11] The evidence is therefore that TFPG in the majority of Singapore's manufacturing industries is affected by input prices. The rise in the price of energy in the 1970s has, by and large, caused a fall in TFPG in many industries. For a smaller number of industries,

[11] "Materials" is used synonymously with non-energy intermediate inputs.

the rise in the price of capital services has had a similar effect. On the other hand, the rise in the price of labor has served to raise TFPG in half of the total number of industries in Singapore.

V. RELATIONSHIP AMONG INPUTS

The estimation of the parameters of the translog price function enable the determination of whether the inputs are substitutes or complements. In order to do this, it is sufficient to examine the sign of the relevant element in the Hessian matrix of second-order partial derivatives [23]. A positive sign denotes that two inputs are substitutes while a negative sign, that they are complements. The following are therefore calculated from the parameter estimates and the average of the value shares over the nine sample points for each industry:[12]

$$\begin{aligned}
\theta_{XX}^i &\equiv \beta_{XX}^i + v_X^i(v_X^i - 1), \\
\theta_{XK}^i &\equiv \beta_{XK}^i + v_X^i v_K^i, \\
\theta_{XL}^i &\equiv \beta_{XL}^i + v_X^i v_L^i, \\
&\vdots \\
\theta_{EE}^i &\equiv \beta_{EE}^i + v_E^i(v_E^i - 1), \quad (i = 1, 2, \cdots, n).
\end{aligned} \tag{20}$$

The θ's for some industries are constrained to be zero because of the imposition of global concavity.[13] They are therefore calculated only when the β's are not constrained to be zero. These are presented in Table III. The results show that materials are substitutes with each of the other three inputs in the twelve industries with nonzero β's. Capital and labor are, on average, substitutes in nine industries and complements in three. Capital and energy, and labor and energy are substitutes in about half the number of industries and complements in the other half.

VI. CONCLUSION

The results of this paper describe the characteristics of technology and production in Singapore's manufacturing industries in the 1970s. Using a data base constructed previously by means of translog indices, translog price functions were estimated for each industry. First, several hypotheses were tested. The results show that, for most of the industries in Singapore, TFPG does not have a constant term nor does it vary systematically with time. However, the rejection of Hicks-neutrality for twenty-two industries implies that TFPG does vary with the prices of inputs. The estimates of the parameters relating to TFPG show that, among

12 The θ's are similar but not equal to the Allen partial elasticities of substitution which are calculated for example, in [2]. The θ's are constrained to be negative as part of the concavity restriction.

13 All the share elasticities are constrained to be zero for thirteen industries. The share elasticities with respect to materials and capital are constrained to be zero for three industries. There are twelve industries for which none of the share elasticities are constrained to be zero. See Appendix Table II.

TABLE III

SUBSTITUTION AND COMPLEMENTARITY AMONG INPUTS

	θ_{XX}^i	θ_{XK}^i	θ_{XL}^i	θ_{XE}^i	θ_{KK}^i	θ_{KL}^i	θ_{KE}^i	θ_{LL}^i	θ_{LE}^i	θ_{EE}^i
Food	−0.331	0.187	0.090	0.054	−0.149	−0.017	−0.021	−0.064	−0.009	−0.024
Beverages	−0.556	0.209	0.319	0.028	−0.214	(0.004)	0.001	−0.312	−0.012	−0.018
Tobacco products	−0.258	0.158	0.088	0.012	−0.157	(0.0001)	−0.002	−0.084	−0.004	−0.007
Wearing apparel	−0.274	0.092	0.174	0.007	−0.108	0.015	0.001	−0.190	(0.00004)	−0.008
Furniture and fixtures	−0.277	0.122	0.141	0.014	−0.161	0.043	−0.005	−0.188	0.003	−0.012
Paper products	−0.333	0.164	0.107	0.062	−0.177	0.021	−0.008	−0.122	−0.006	−0.047
Petroleum products	−0.151	0.108	0.009	0.035	−0.110	0.004	−0.001	−0.020	0.007	−0.040
Rubber products	−0.332	0.170	0.131	0.031	−0.212	0.036	0.005	−0.167	(−0.001)	−0.035
Nonmetallic mineral products	−0.284	0.165	0.093	0.026	−0.210	0.043	0.001	−0.135	−0.001	−0.026
Nonferrous metal products	−0.284	0.165	0.093	0.026	−0.167	(−0.0004)	(0.001)	−0.136	(0.001)	−0.021
Fabricated metal products	−0.237	0.120	0.096	0.022	−0.160	0.029	0.012	−0.131	0.007	−0.040
Electrical machinery	−0.507	0.204	0.235	0.069	−0.190	(−0.004)	−0.011	−0.198	−0.034	−0.025
Textiles								−0.142	0.012	−0.043
Timber products								−0.124	0.006	−0.022
Printing and publishing								−0.183	0.003	−0.011

Notes: 1. Average figures.
2. The parentheses denote that switching of signs has occurred over the sample points.

these twenty-two industries, TFPG increased with the rise in the price of labor input in fourteen industries, and decreased with the rise in the prices of energy and capital in eighteen and fourteen industries respectively. Second, hypotheses relating to the existence of a price of value-added function and the separability of capital and energy were also tested. These hypotheses were rejected for the majority of industries, indicating that there is little evidence for such separability of inputs in the production structure. Third, the relationship among inputs was investigated. The most common pattern was that materials are substitutes for the other three inputs, and to a lesser extent that capital and labor are also substitutes.

There are a number of qualifications which need to be mentioned regarding the quality of the results discussed above. The major weaknesses of the data base, as expected, pertain to the construction of the capital input indices for each industry and hence the price indices of capital input [21] [22]. The assumption of constant returns to scale may also not be valid. If there are non-constant returns to scale then the TFPG figures will be biased because they will then include the output changes due to the scale factor [5]. The sample size, that is, the time series, is also not as large as one would prefer because of classification constraints.

One direction for future research would be to make further refinements to the industry studies which have been carried out so far in the neoclassical tradition.[14] These can, for example, take the form of improvements to the data base, if and when new data become available in Singapore. It could be, however, that studies of this nature are fast yielding diminishing returns [17]. More micro-level studies, such as at the firm or intra-firm level, which specifically investigate the nature of technical inefficiency [16], or relate differences in total factor productivity to, for example, differences in human resource management practices [19], may be more illuminating as to what the determinants of efficiency in production are. There is wide scope for research in this area in Singapore where productivity improvement is a much emphasized policy goal.

[14] This is as opposed to the estimation of frontier production functions as, for example, in [4].

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APPENDIX TABLE I

TEST STATISTICS: STANDARD NORMAL (HYPOTHESES 1 AND 2) AND $-2\ln\lambda$ (HYPOTHESES 3 THROUGH 7)

Industry	Hypothesis									
	1	2	3	3a	4	4a	5	6	6a	7
Food	−0.0541	−0.0984	38.421		17.244		133.636	4.503	17.601	35.781
Beverages	−0.627	0.442	13.245		43.726		36.003	21.740		45.234
Tobacco products	−0.121	−0.382	23.615		6.138	20.248	62.037	25.537		32.124
Textiles	0.269	0.0172	35.892		29.468		33.330	19.835		37.759
Wearing apparel	−0.0454	0.220	11.461		47.188		106.110	16.874		55.898
Leather products	0.263	−0.270	23.173		12.466	11.179	61.326	8.023	28.152	30.418
Footwear	−0.841	2.833	11.091	10.507	2.125	7.718	38.958	1.351	18.106	14.445
Timber products	−0.226	0.838	29.767		3.967	35.908	19.233	25.054		44.115
Furniture and fixtures	0.150	−0.174	27.621		2.944	26.688	44.904	34.045		51.323
Paper products	0.0120	0.0282	9.607	0.690	12.708	22.750	34.218	9.067	11.210	38.675
Printing and publishing	0.895	−0.827	8.651	16.459	3.283	21.329	24.112	0.291	21.148	2.811
Industrial chemicals	−0.0112	0.147	20.077		19.035		64.056	23.212		33.410
Chemical products	0.0255	−0.00483	21.957		23.101		27.246	5.540	26.304	16.472
Petroleum products	0.428	−0.749	4.019	0.932	9.309	32.920	36.228	11.902	4.926	39.401
Jelutong processing	−0.177	−0.0277	4.906	0.247	7.371	28.788	18.879	5.187	6.004	26.904
Rubber products	−1.104	1.493	13.055		3.963	32.433	45.497	16.005		65.811
Plastic products	−0.526	0.916	36.639		16.585		141.147	39.713		44.548
Pottery and glass products	0.668	−0.373	85.495		71.287		98.675	41.889		94.088
Clay products	−0.308	0.307	37.198		12.241	15.679	48.457	21.813		36.077
Cement	0.310	−0.0232	21.248		1.782	26.702	29.368	13.177		21.447
Concrete products	0.128	0.265	26.279		26.300		53.736	24.037		24.888
Nonmetallic mineral products	1.489	−1.759	106.466		87.348		125.722	84.282		85.497
Iron and steel	0.311	−0.183	28.580		42.350		47.594	18.992		65.644
Nonferrous metal products	−0.205	0.704	6.497	0.901	3.462	7.395	6.121	4.321	7.024	4.454
Fabricated metal products	0.334	−0.0765	16.771		13.183	7.006	37.423	19.640		20.234
Industrial machinery	0.303	−0.355	21.748		16.311		28.429	0.113	26.099	15.094
Electrical machinery	0.267	−0.387	19.994		20.283		41.358	14.064		26.738
Transport equipment	−0.0909	−0.134	26.906		8.637	1.454	42.331	12.377	34.648	20.101

Note: At the 0.005 significance level, the critical values of the test statistics are: (1) standard normal (hypotheses 1 and 2): 2.5758; (2) X_2^2 (hypotheses 3a and 4a): 10.597; (3) X_3^2 (hypotheses 3, 6, and 6a): 12.838; (4) X_4^2 (hypotheses 4 and 7): 14.860; and (5) X_7^2 (hypothesis 5): 20.278.

APPENDIX

PARAMETER ESTIMATES OF

	Food		Beverages		Tabacco Products	
α_X^i	0.830	(0.0113)	0.453	(0.0177)	0.743	(0.0155)
α_K^i	0.104	(0.00741)	0.342	(0.0185)	0.219	(0.0124)
α_L^i	0.0560	(0.00375)	0.191	(0.00549)	0.0358	(0.00345)
α_E^i	0.00988	(0.00146)	0.0147	(0.000818)	0.00231	(0.000634)
α_T^i	−0.00443	(0.0867)	−0.0562	(0.0893)	−0.0109	(0.0885)
β_{XX}^i	−0.182	(0.0650)	−0.309	(0.0282)	−0.0703	(0.0178)
β_{XK}^i	0.0964	(0.0349)	0.0563	(0.0198)	0.0178	(0.00696)
β_{XL}^i	0.0431	(0.0286)	0.233	(0.0217)	0.0432	(0.0135)
β_{XE}^i	0.0422	(0.0102)	0.0195	(0.00314)	0.00934	(0.00160)
β_{XT}^i	−0.00252	(0.00180)	0.00783	(0.00289)	0.00207	(0.00251)
β_{KK}^i	−0.0511	(0.0211)	−0.0103	(0.00669)	−0.00449	(0.00269)
β_{KL}^i	−0.0229	(0.0142)	−0.0425	(0.0122)	−0.0109	(0.00420)
β_{KE}^i	−0.0224	(0.00427)	−0.00355	(0.00120)	−0.00236	(0.000658)
β_{KT}^i	−0.00120	(0.00118)	−0.00808	(0.00299)	−0.00587	(0.00200)
β_{LL}^i	−0.0102	(0.0102)	−0.176	(0.0243)	−0.0284	(0.0110)
β_{LE}^i	−0.0100	(0.00502)	−0.0147	(0.00246)	−0.00388	(0.00160)
β_{LT}^i	0.000344	(0.000621)	−0.000538	(0.000913)	0.00364	(0.000505)
β_{EE}^i	−0.00980	(0.00405)	−0.00123	(0.000392)	−0.00311	(0.000769)
β_{ET}^i	0.000976	(0.000226)	−0.000792	(0.000140)	0.000168	(0.0000998)
β_{TT}^i	−0.00143	(0.0140)	0.00621	(0.0145)	−0.00563	(0.0143)

	Footwear		Timber Products		Furniture and Fixtures	
α_X^i	0.615	(0.0136)	0.671	(0.0157)	0.520	(0.0218)
α_K^i	0.142	(0.0205)	0.142	(0.0210)	0.205	(0.0225)
α_L^i	0.232	(0.0172)	0.171	(0.0108)	0.261	(0.0163)
α_E^i	0.0114	(0.000673)	0.0160	(0.00286)	0.0134	(0.00132)
α_T^i	−0.0385	(0.0541)	−0.0410	(0.188)	0.0378	(0.223)
β_{XX}^i					−0.0332	(0.0205)
β_{XK}^i					0.0289	(0.0157)
β_{XL}^i					−0.00325	(0.00714)
β_{XE}^i					0.00756	(0.00177)
β_{XT}^i	0.00273	(0.00220)	0.00137	(0.00253)	0.00738	(0.00263)
β_{KK}^i					−0.0251	(0.0144)
β_{KL}^i					0.00283	(0.00689)
β_{KE}^i					−0.00657	(0.00103)
β_{KT}^i	−0.00117	(0.00331)	0.00356	(0.00340)	−0.00509	(0.00298)
β_{LL}^i			−0.00301	(0.00477)	−0.000319	(0.00153)
β_{LE}^i			0.00301	(0.00477)	0.000741	(0.00179)
β_{LT}^i	−0.00164	(0.00279)	−0.00546	(0.00175)	−0.00243	(0.00243)
β_{EE}^i			−0.00301	(0.00477)	−0.00172	(0.000556)
β_{ET}^i	0.0000788	(0.000109)	0.000529	(0.000455)	0.000150	(0.000168)
β_{TT}^i	0.0239	(0.00869)	0.0254	(0.0304)	−0.00666	(0.0360)

TABLE II

THE TRANSLOG PRICE MODEL

Textiles		Wearing Apparel		Leather Products	
0.661	(0.0159)	0.717	(0.0115)	0.828	(0.0152)
0.153	(0.0250)	0.0785	(0.0120)	0.0712	(0.0180)
0.164	(0.00798)	0.197	(0.00665)	0.0958	(0.0111)
0.0228	(0.00530)	0.00788	(0.000967)	0.00487	(0.000477)
0.0643	(0.229)	−0.0252	(0.560)	0.0665	(0.203)
		−0.0577	(0.0336)		
		0.00928	(0.00929)		
		0.0467	(0.0335)		
		0.00177	(0.00309)		
−0.00359	(0.00256)	−0.00802	(0.00164)	−0.0115	(0.00246)
		−0.00149	(0.00323)		
		−0.00751	(0.00590)		
		−0.000285	(0.000465)		
0.00107	(0.00404)	0.00786	(0.00191)	0.00701	(0.00291)
−0.00603	(0.000881)	−0.0378	(0.0339)		
0.00603	(0.000881)	−0.00138	(0.00268)		
−0.000316	(0.00129)	0.000127	(0.000828)	0.00467	(0.00179)
−0.00603	(0.000881)	−0.000107	(0.000711)		
0.00284	(0.000857)	0.0000355	(0.000129)	−0.000152	(0.0000771)
0.000482	(0.0372)	0.0199	(0.0906)	−0.0105	(0.0328)

Paper Products		Printing and Publishing		Industrial Chemicals	
0.659	(0.0135)	0.430	(0.0152)	0.454	(0.0505)
0.219	(0.0148)	0.297	(0.0221)	0.364	(0.0410)
0.117	(0.00605)	0.261	(0.0106)	0.133	(0.0127)
0.00483	(0.00590)	0.0117	(0.000564)	0.0499	(0.00441)
0.00617	(0.334)	0.0881	(0.0985)	0.000937	(0.0291)
−0.0982	(0.0314)				
0.0311	(0.0124)				
0.0231	(0.0154)				
0.0439	(0.0169)				
−0.00680	(0.00233)	0.00514	(0.00246)	0.0223	(0.00817)
−0.00987	(0.00670)				
−0.00733	(0.00349)				
−0.0139	(0.00575)				
−0.000838	(0.00239)	−0.00144	(0.00358)	−0.0162	(0.00663)
−0.00545	(0.00624)	−0.000588	(0.000730)		
−0.0103	(0.00652)	0.000588	(0.000730)		
0.00321	(0.00106)	−0.00351	(0.00172)	−0.00625	(0.00205)
−0.0197	(0.0101)	−0.000588	(0.000730)		
0.00443	(0.00104)	−0.000200	(0.0000876)	0.000109	(0.000712)
0.00133	(0.0541)	−0.0131	(0.0159)	0.00651	(0.0471)

APPENDIX

	Chemical Products		Petroleum Products		Jelutong Processing	
α_X^i	0.580	(0.0107)	0.786	(0.00999)	0.872	(0.0092)
α_K^i	0.285	(0.0168)	0.164	(0.00860)	0.0660	(0.00840)
α_L^i	0.128	(0.00654)	0.0290	(0.00285)	0.0557	(0.00392)
α_E^i	0.00748	(0.000452)	0.0206	(0.00430)	0.00659	(0.000859)
α_T^i	0.0104	(0.390)	0.0359	(0.0700)	−0.0496	(0.300)
β_{XX}^i			−0.0140	(0.00640)		
β_{XK}^i			0.00348	(0.00278)		
β_{XL}^i			−0.00586	(0.00444)		
β_{XE}^i			0.0164	(0.0105)		
β_{XT}^i	−0.0131	(0.00174)	0.00875	(0.00161)	0.00105	(0.00149)
β_{KK}^i			−0.000865	(0.00146)		
β_{KL}^i			0.00146	(0.00156)		
β_{KE}^i			−0.00407	(0.00291)		
β_{KT}^i	0.0163	(0.00272)	−0.00689	(0.00139)	−0.00196	(0.00136)
β_{LL}^i			−0.00246	(0.00294)		
β_{LE}^i			0.00686	(0.00659)		
β_{LT}^i	−0.00350	(0.00106)	−0.00212	(0.000487)	0.000109	(0.000634)
β_{EE}^i			−0.0192	(0.0164)		
β_{ET}^i	0.000337	(0.0000731)	0.000255	(0.000740)	0.000803	(0.000139)
β_{TT}^i	−0.000348	(0.0631)	−0.00940	(0.0113)	−0.00216	(0.0485)

	Clay Products		Cement		Concrete Products	
α_X^i	0.130	(0.0102)	0.737	(0.0275)	0.676	(0.0175)
α_K^i	0.459	(0.0333)	0.183	(0.0302)	0.133	(0.0158)
α_L^i	0.300	(0.0195)	0.0450	(0.00235)	0.182	(0.0107)
α_E^i	0.112	(0.0252)	0.0354	(0.00349)	0.00888	(0.00239)
α_T^i	−0.0933	(0.377)	0.0396	(0.128)	0.0382	(0.215)
β_{XX}^i						
β_{XK}^i						
β_{XL}^i						
β_{XE}^i						
β_{XT}^i	−0.00701	(0.00164)	−0.00265	(0.00444)	−0.00467	(0.00283)
β_{KK}^i						
β_{KL}^i						
β_{KE}^i						
β_{KT}^i	−0.0106	(0.00538)	0.00457	(0.00488)	0.0113	(0.00255)
β_{LL}^i						
β_{LE}^i						
β_{LT}^i	−0.00454	(0.00315)	−0.00152	(0.000380)	−0.00685	(0.00173)
β_{EE}^i						
β_{ET}^i	0.0221	(0.00408)	−0.000402	(0.000564)	0.000205	(0.000386)
β_{TT}^i	0.0135	(0.0610)	−0.000516	(0.0207)	0.00726	(0.0348)

TABLE II (Continued)

Rubber Products		Plastic Products		Pottery and Glass Products	
0.443	(0.0304)	0.616	(0.0199)	0.365	(0.0265)
0.364	(0.0211)	0.227	(0.0212)	0.202	(0.0429)
0.170	(0.0119)	0.138	(0.00976)	0.332	(0.0303)
0.0224	(0.00264)	0.0188	(0.00151)	0.101	(0.0156)
−0.0784	(0.0760)	−0.0166	(0.321)	0.142	(0.197)
−0.0829	(0.0354)				
0.0268	(0.0323)				
0.0426	(0.0313)				
0.0135	(0.0106)				
0.00833	(0.00401)	0.00209	(0.00322)	0.00702	(0.00429)
−0.00864	(0.0195)				
−0.0138	(0.0117)				
−0.00436	(0.00346)				
−0.0131	(0.00270)	−0.00450	(0.00343)	0.00572	(0.00694)
−0.0219	(0.0268)				
−0.00694	(0.00777)				
0.00223	(0.00165)	0.000583	(0.00158)	−0.0175	(0.00490)
−0.0220	(0.00357)				
0.00258	(0.000457)	0.00182	(0.000245)	0.00481	(0.00252)
0.0177	(0.0123)	0.0470	(0.0518)	−0.0145	(0.0319)

Nonmetallic Mineral Products		Iron and Steel		Nonferrous Metal Products	
0.524	(0.0208)	0.620	(0.0594)	0.678	(0.0350)
0.241	(0.0305)	0.212	(0.0665)	0.209	(0.0297)
0.214	(0.0146)	0.103	(0.00689)	0.0857	(0.0263)
0.0207	(0.00285)	0.0644	(0.00715)	0.0272	(0.00558)
0.672	(0.452)	0.0525	(0.204)	−0.111	(0.548)
−0.0354	(0.0273)			−0.125	(0.0780)
0.00999	(0.00870)			0.0440	(0.0174)
0.00931	(0.0199)			0.0771	(0.0619)
0.0161	(0.00780)			0.00419	(0.0168)
0.000212	(0.00329)	−0.0252	(0.00960)	0.00887	(0.00572)
−0.00282	(0.00299)			−0.0271	(0.0185)
−0.00263	(0.00558)			−0.0140	(0.0146)
−0.00454	(0.00290)			−0.00290	(0.00391)
0.00903	(0.00493)	0.0220	(0.0107)	−0.00714	(0.00464)
−0.00245	(0.00882)			−0.0621	(0.0515)
−0.00423	(0.00565)			−0.000977	(0.0166)
−0.00959	(0.00235)	−0.00195	(0.00111)	−0.000598	(0.00424)
−0.00731	(0.00826)			−0.000315	(0.00101)
0.000341	(0.000483)	0.00518	(0.00116)	−0.00113	(0.000996)
−0.128	(0.0730)	−0.00643	(0.0324)	0.0622	(0.0886)

APPENDIX

	Fabricated Metal Products		Industrial Machinery		Electrical Machinery	
$\alpha_X{}^i$	0.650	(0.00753)	0.626	(0.0194)	0.489	(0.0323)
$\alpha_K{}^i$	0.184	(0.00993)	0.190	(0.0282)	0.331	(0.0245)
$\alpha_L{}^i$	0.152	(0.00658)	0.171	(0.0130)	0.159	(0.00708)
$\alpha_E{}^i$	0.0149	(0.00147)	0.0134	(0.000945)	0.0214	(0.00242)
$\alpha_T{}^i$	0.0807	(0.241)	0.0858	(0.286)	0.0340	(0.103)
$\beta_{XX}{}^i$	−0.00511	(0.00471)			−0.277	(0.0307)
$\beta_{XK}{}^i$	−0.00390	(0.00152)			0.0588	(0.0107)
$\beta_{XL}{}^i$	−0.00185	(0.00204)			0.157	(0.0227)
$\beta_{XE}{}^i$	0.0108	(0.00534)			0.0619	(0.00621)
$\beta_{XT}{}^i$	−0.00283	(0.00121)	−0.0151	(0.00314)	0.0189	(0.00518)
$\beta_{KK}{}^i$	−0.00298	(0.00158)			−0.124	(0.00368)
$\beta_{KL}{}^i$	−0.00141	(0.00196)			−0.0332	(0.00666)
$\beta_{KE}{}^i$	0.00829	(0.00239)			−0.0131	(0.000819)
$\beta_{KT}{}^i$	0.00217	(0.00167)	0.0137	(0.00457)	−0.0156	(0.00395)
$\beta_{LL}{}^i$	−0.000667	(0.00182)			−0.0886	(0.0160)
$\beta_{LE}{}^i$	0.00392	(0.00571)			−0.0350	(0.00398)
$\beta_{LT}{}^i$	0.000128	(0.00106)	0.000821	(0.00210)	−0.00280	(0.00108)
$\beta_{EE}{}^i$	−0.0231	(0.00668)			−0.0138	(0.00304)
$\beta_{ET}{}^i$	0.000529	(0.000255)	0.000579	(0.000153)	−0.000480	(0.000411)
$\beta_{TT}{}^i$	−0.00302	(0.0390)	−0.0170	(0.0461)	−0.00730	(0.0167)

Note: The standard errors are given in parentheses.

TABLE II (Continued)

Transport Equipment	
0.507	(0.00610)
0.198	(0.00646)
0.278	(0.0103)
0.0173	(0.000837)
−0.0113	(0.134)
0.000136	(0.000987)
0.00989	(0.00104)
−0.0101	(0.00166)
0.0000858	(0.000135)
−0.00296	(0.0216)