

Import Demand, Factor Substitution and Technological Change for Korea, Taiwan and Japan: The Translog Cost Function Approach

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I. Introduction

Much of the economic success of Korea, Japan and Taiwan has been attributable to foreign trade and technical change, and the spectacular growth of these three economies has attracted much scholarly attention in recent years. The present study provides the quantitative dimensions of import demand function and technical change for three economies, and pays attention to the contrasts and similarities in the results among the three economies. These contrasts and similarities will provide valuable insight for better understanding of the development process.

While imports are treated as either final goods of intermediate goods which are separable from primary factors in the traditional approach,¹⁾ it would be more reasonable to treat imports as a factor input. A small number of studies²⁾ have recently verified the role of imports as a factor input which is important as substitutes or complements for domestic primary inputs.

The specific objectives of this study are as follows: First, it examines the role of imports in Korea, Japan and Taiwan for the period of 1964-83. Second, it uses decomposition analysis to see the effect of technical changes on input demand and to estimate biases of technical change. Third, it makes intercountry comparison of the results and discuss the implications of our findings.

In order to estimate the import demand function, we use the translog cost function approach as it overcomes several serious deficiencies inherent in the conventional functional form such as Cobb-Douglas and CES functions. The translog enables us to estimate the import demand

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1) For reviews of the methodology, see Leamer and Stern (1970), and Stern, Francis, and Schumacher (1976).

2) See the works by Burgess (1974a, b), Kohli (1978), Appelbauan and Kohli (1979), and Mohabbat, Dalal, and Williams (1984).

without imposing any a priori restrictions on input substitutability or separability among inputs and outputs, and to test hypotheses about substitutability and various separabilities. Input-output separability implies that the composition of outputs does not affect the cost-minimizing mix of inputs for given factor prices. The verification of input-output separability is of significance for three countries because of substantial change in the mix of consumption goods, investment goods and exports. In addition we also test the hypothesis of separability among inputs. The non-existence of such separability implies that it would be inappropriate to treat the import demand as depending only on import prices and GNP, as is done in most traditional approach to the estimation of import demand. Further, the translog cost function enables us to calculate the Allen Partial Elasticities of substitution (AES) between pairs of inputs, and thus to make judgement about input substitutability or complementarity.

The existing literature on the measurement of technical change is limited in scope in evaluating the process of technical change for developing economies.³⁾ Furthermore, little attempt has been made to analyse the growth of factor input demand through the decomposition of factor input demand (Kako (1978), and Berndt and Khaled (1979)). From a policy perspective, the measurement of technical change is important for forecasting growth prospects and allocating scarce resources.

In sections II and III, we discuss the methodology and data, and in section IV we analyse the empirical results along with their policy implications. Summary and conclusions are given in section V.

II. The Model with Technical Change

A system of import demand function will be derived in an attempt to avoid some of the more serious shortcomings of the traditional approach. Import and export decisions are assumed to be made by cost minimizing firms operating in the purely competitive market for inputs and outputs. Imports and exports are considered respectively as inputs to, and outputs of, the technology. Under these conditions the technology of production can be defined by a transformation function $t(Q;X)=0$ where Q is a vector of outputs and X is a vector of inputs. If $t(Q;X)$ is continuous for all nonnegative Q and X and the input requirement set $X(Q)=(X|t(Q;X)\geq 0)$

3) See Berndt and Khaled (1979), Binswanger (1974), Kako (1978), Kopp and Smith (1981).

is closed and strictly convex, then there exists a unique cost function $C(Q; W)$ due to duality principle differentiable with respect to Q and W where W is a vector of factor prices. $C(Q; W)$ is defined by,

$$C(Q; W) = \min W'X \quad \text{s.t.} \quad X \in X(Q). \quad (1)$$

The cost function is the formulation adopted in this paper to describe the technology.

The production sector for a country will be approximated with a model that has three outputs and three inputs. The outputs are consumption goods (C), investment goods (I) and exports (X). The inputs are the services of capital (K) and labor (L) and imports (M). The following accounting identity is used to connect the total value of the outputs to that of the inputs:

$$P_C Q_C + P_I Q_I + P_X Q_X = W_L X_L + W_K X_K + W_M X_M \quad (2)$$

The aggregate joint cost function will be approximated using the translog function.

$$\begin{aligned} \ln C = & \alpha_0 + \sum_i \alpha_i \ln W_i + \sum_k \beta_k \ln Q_k + \gamma_t \ln T + \frac{1}{2} \sum_i \sum_j \delta_{ij} \ln W_i \ln W_j \\ & + \frac{1}{2} \sum_{k,l} \theta_{kl} \ln Q_k \ln Q_l + \sum_i \sum_k \rho_{ik} \ln W_i \ln Q_k + \ln T \sum_i \gamma_{it} \ln W_i \\ & + \ln T \sum_k \gamma_{kt} \ln Q_k + \frac{1}{2} \gamma_{tt} (\ln T)^2 \\ & i, j = K, L, M, \quad k, l = C, I, K \end{aligned} \quad (3)$$

We consider the following as maintained hypothesis:

(1) The symmetry constraints require

$$a) \quad \delta_{ij} = \delta_{ji} \quad b) \quad \rho_{ik} = \rho_{ki} \quad c) \quad \theta_{kl} = \theta_{lk} \quad (4)$$

(2) The cost function is linearly homogeneous in the input prices W_i and this requires the parameter restrictions⁴⁾

$$\begin{aligned} a) \quad \sum_i \alpha_i &= 1 \quad b) \quad \sum_i \sum_j \delta_{ij} = \sum_i \delta_{ij} = \sum_j \delta_{ij} = 0 \quad c) \quad \sum_i \sum_k \rho_{ik} = 0 \\ d) \quad \sum_i \gamma_{it} &= 0 \end{aligned} \quad (5)$$

(3) Linear homogeneity of the production function in inputs requires

4) Linear homogeneity in input prices is defined as follows: $C(\lambda W, Q, T) = C(W, Q, T)$ or $\ln C(\lambda W, Q, T) = \ln \lambda + \ln C(W, Q, T)$. Substitute λW for W in equation and we get $\ln C(\lambda W, Q, T) = \ln C(W, Q, T) + \ln \lambda \sum_i \alpha_i + \frac{1}{2} (\ln \lambda)^2 \sum_i \sum_j \delta_{ij} + \frac{1}{2} \ln \lambda \sum_i \sum_j \delta_{ij} \ln W_i + \frac{1}{2} \ln \lambda \sum_i \sum_j \delta_{ij} \ln W_j + \ln \lambda \sum_i \sum_k \rho_{ik} \ln Q_k + \ln T \sum_i \gamma_{it} \ln W_i + \ln \lambda$. This implies that $\sum_i \alpha_i = 1$, $\sum_i \sum_j \delta_{ij} = \sum_i \delta_{ij} = \sum_j \delta_{ij} = 0$, $\sum_i \sum_k \rho_{ik} = 0$, $\sum_i \gamma_{it} = 0$.

additional constraints:⁵⁾

$$\begin{aligned} \text{a) } \sum_k \beta_k &= 1 & \text{b) } \sum_k \sum_l \theta_{kl} &= \sum_k \theta_{k1} = \sum_l \theta_{kl} = 0 & \text{c) } \sum_l \rho_{ik} &= 0 \\ \text{d) } \sum_k \gamma_{kt} &= 0 \end{aligned} \quad (6)$$

Differentiating (3) logarithmically with respect to input prices and output quantities, using Shephard' lemma, and incorporating the maintained restrictions, we obtain the share equations.

$$\begin{aligned} S_K &= \frac{\partial \ln C}{\partial \ln W_K} = \alpha_K + \delta_{KK} \ln \frac{W_K}{W_L} + \delta_{KM} \ln \frac{W_M}{W_L} + \rho_{KC} \ln \frac{Q_C}{Q_I} + \rho_{KX} \ln \frac{Q_X}{Q_I} + \gamma_{Kt} \ln T \\ S_M &= \frac{\partial \ln C}{\partial \ln W_M} = \alpha_M + \delta_{MM} \ln \frac{W_M}{W_L} + \delta_{KM} \ln \frac{W_K}{W_L} + \rho_{MC} \ln \frac{Q_C}{Q_I} + \rho_{MX} \ln \frac{Q_X}{Q_I} + \gamma_{Mt} \ln T \\ R_C &= \frac{\partial \ln C}{\partial \ln Q_C} = \beta_C + \theta_{CC} \ln \frac{Q_C}{Q_I} + \theta_{CX} \ln \frac{Q_X}{Q_I} + \rho_{CK} \ln \frac{W_K}{W_L} + \rho_{MC} \ln \frac{W_M}{W_L} + \gamma_{Ct} \ln T \\ R_X &= \frac{\partial \ln C}{\partial \ln Q_X} = \beta_X + \theta_{XX} \ln \frac{Q_X}{Q_I} + \theta_{CX} \ln \frac{Q_C}{Q_I} + \rho_{KX} \ln \frac{W_K}{W_L} + \rho_{MX} \ln \frac{W_M}{W_L} + \gamma_{Xt} \ln T \end{aligned} \quad (7)$$

Where S_K and S_M are the cost shares of capital and imports, and R_C and R_X the revenue shares of consumption goods and exports respectively. The δ_{ij} , ρ_{ik} , and θ_{kl} parameters have little economic meaning of their own. They are related to various elasticities of substitution and of factor demand. The cost share equation of labor and the revenue share equation of investment are omitted because n-1 cost share and m-1 revenue share equations are independent.

The four equations (7) with additive error terms for cost minimization will be used to estimate the parameters of the translog function. The procedure used is the Zellner's seemingly unrelated regression estimation to estimate the parameters of the cost and revenue share equations. The iteration of Zellner's estimation procedure until convergence yields maximum likelihood estimates which are invariant to the omitted equations.⁶⁾

Our tests for hypothesis are based on the likelihood ratio (λ) method, indicating that $-2 \ln \lambda$ is asymptotically distributed as χ^2 and unbiased

5) Constant returns to scale (linear homogeneity of the production function in inputs) implies that $C(W, Q, T) = Q \cdot g(W, T)$ or $\ln C(W, Q, T) = \ln Q + \ln g(W, T)$.

6) See Kmenta and Gilbert (1968).

with the number of degrees of freedom equal to the number of independent restrictions imposed.

The translog functional form enables us to compute AES between inputs with the parameter estimates of cost function and the fitted cost shares, and without any a priori restrictions being imposed. In general, the AES between inputs i and j can be written as⁷⁾

$$\sigma_{ij} = CC_{ij} / C_i C_j = \varepsilon_{ij} / S_j \quad (8)$$

where $C_{ij} = \partial^2 C / \partial W_i \partial W_j$, $C_i = \partial C / \partial W_i$, ε_{ij} is compensated price elasticity of i th input with respect to j th price since Q is constant, and S_j the j th input cost share.

In terms of the estimated parameters of translog cost function and the fitted cost shares, Equation (8) can be expressed as⁸⁾

$$\sigma_{ij} = \frac{\delta_{ij}}{S_i S_j} + 1 \quad (9)$$

Also, the own elasticity of substitution (σ_{ii}) can be expressed as following

$$\sigma_{ii} = \frac{\delta_{ii} + S_i^2 - S_i}{S_i^2} \quad (10)$$

If the technology is separable with respect to a partitioning between outputs and inputs, the translog joint cost function can be written as $\ln C(Q; W; T) = \ln G(Q) + \ln H(W, T)$ which implies that the interaction terms between outputs and input prices must be vanished. In terms of the parameters of our model the existence of input-output separability requires setting the parameters of the terms involving interaction between input and output equal to 0.

7) See Layard and Walters (1978).

8) $\sigma_{ij} = \frac{CC_{ij}}{C_i C_j}$ $S_i = \frac{\partial \ln C}{\partial \ln W_i} = \frac{\partial C}{\partial W_i} \frac{W_i}{C} = \frac{C_i W_i}{C}$ $C_i = \frac{S_i C}{W_i}$ $C_j = \frac{S_j C}{W_j}$

By differentiating C_i with respect to W_j ,

$$C_{ij} = \frac{1}{W_i} \left[\frac{\partial S_i}{\partial W_j} + S_i C_j \right] \text{ since } W_i \text{ is constant,}$$

$$= \frac{1}{W_i} \frac{\partial S_i}{\partial \ln W_j} \cdot \frac{C}{W_j} + S_i \frac{S_j C}{W_j} = \frac{C}{W_i W_j} \left[\frac{\partial S_i}{\partial \ln W_j} + S_i S_j \right]$$

Through substitution of the relevant terms, we get

$$\sigma_{ij} = \frac{\frac{C}{W_i W_j} \frac{\partial S_i}{\partial \ln W_j} + S_i S_j}{\frac{S_i C}{W_i} \frac{S_j C}{W_j}} = \frac{\delta_{ij} + S_i S_j}{S_i S_j} = \frac{\delta_{ij}}{S_i S_j} + 1$$

Separable production structure can be inferred from a separable cost function. The AES measures the response of derived demand to an input price change, holding output and all other input prices fixed. Separability restrictions on production and cost functions are equivalent to certain equality restrictions in the AES. The weak separability between W_i and W_j from W_k exists if and only if $\sigma_{ik} = \sigma_{jk}$ for homothetic production function.

The existence of linear separability between factors would hold if $\sigma_{ik} = \sigma_{jk} = 1$. If $\sigma_{ik} = \sigma_{jk} \neq 1$, there would exist nonlinear separability. In terms of the parameters of the model the test for the existence of linear separability between pairs of inputs, involves imposing the additional restrictions.

(1) For linear separability between primary factors (K, L) and imports, the additional restrictions imposed are $\delta_{KM} = \delta_{MM} = 0$.

(2) For the case of (K, M) and L, the restrictions are $\delta_{KK} = -\delta_{KM} = \delta_{MM}$.

(3) For the case of (L, M) and K, the restrictions are $\delta_{KK} = \delta_{KM} = 0$.

Finally, the existence of non-linear separability imposes the following restrictions.

(1) The existence of non-linear separability between primary factors and import requires that $\delta_{KM}(1-S_M) = -S_K\delta_{MM}$. In terms of the parameters of the model the restrictions are:

$$\begin{aligned}
 \text{a) } \alpha_M &= 1 + \frac{\delta_{KM}}{\delta_{KK}} \alpha_K & \text{d) } \rho_{MX} &= \frac{\delta_{MM}}{\delta_{KM}} \rho_{KX} = \frac{\delta_{KM}}{\delta_{KK}} \rho_{KX} \\
 \text{b) } \delta_{MM} &= \frac{\delta_{KM}^2}{\delta_{KK}} & \text{e) } \gamma_{Mt} &= \frac{\delta_{KM} \cdot \gamma_{Kt}}{\delta_{MM}} = \frac{\delta_{KK}}{\delta_{KM}} \cdot \gamma_{Kt} \\
 \text{c) } \rho_{MC} &= \frac{\delta_{MM}}{\delta_{KM}} \rho_{KC} = \frac{\delta_{KM}}{\delta_{KK}} \rho_{KC} & & (11)
 \end{aligned}$$

(2) The existence of non-linear separability between (K, M) and L implies that

$$S_M (\delta_{KK} + \delta_{KM}) = S_K (\delta_{MM} + \delta_{KM}).$$

In terms of the parameters of the model, by substituting for S_M and S_K .

$$\begin{aligned}
 \text{a) } \delta_{KK} &= \frac{\delta_{KM}^2}{\delta_{MM}} \\
 \text{b) } \alpha_K &= \frac{\delta_{KK} + \delta_{KM}}{\delta_{MM} + \delta_{KM}} \quad \alpha_M = \frac{\delta_{KM}}{\delta_{MM}} \alpha_M & \text{c) } \rho_{KC} &= \frac{\delta_{KK} + \delta_{KM}}{\delta_{MM} + \delta_{KM}} \rho_{MC} = \frac{\delta_{KM}}{\delta_{MM}} \rho_{MC}
 \end{aligned}$$

$$d) \quad \rho_{KX} = \frac{\delta_{KK} + \delta_{KM}}{\delta_{MM} + \delta_{KM}} \rho_{MX} = \frac{\delta_{KM}}{\delta_{MM}} \rho_{MX} \quad e) \quad \gamma_{Kt} = \frac{\delta_{MM} + \delta_{KM}}{\delta_{KK} + \delta_{KM}} \gamma_{Mt} = \frac{\delta_{KM}}{\delta_{MM}} \gamma_{Mt} \quad (11)$$

(3) The existence of non-linear separability between (L, M) and K implies that

$$-\delta_{KK}S_M = \delta_{KM} - S_K\delta_{KM}.$$

In terms of the parameters of the model the restrictions are

$$\begin{aligned} a) \quad \delta_{KK} &= \frac{\delta_{KM}^2}{\delta_{MM}} & b) \quad \alpha_K &= \frac{\delta_{KK}}{\delta_{KM}} \alpha_M + 1 = \frac{\delta_{KM}}{\delta_{MM}} \alpha_M + 1 \\ c) \quad \rho_{KC} &= \frac{\delta_{KM}}{\delta_{MM}} \rho_{MC} & d) \quad \rho_{KX} &= \frac{\delta_{KM}}{\delta_{MM}} \rho_{MX} \\ e) \quad \gamma_{Kt} &= \frac{\delta_{KM}}{\delta_{MM}} \gamma_{Mt} \end{aligned} \quad (12)$$

Separability means that input can be aggregated if an input is separable from all other inputs, i.e., a consistent aggregate index may exists for that input.

Decomposition Analysis of Technical Change

The Hicksian definition of technical change is used in this study. According to Hicks, technical progress is neutral if the marginal rate of substitution between capital and labor is unchanged under technical change at given factor proportions. By the same token, technical change is defined as Hicks' labor saving if the marginal product of capital is raised relative to that of labor, given factor proportions, and is labor using if the opposite is true. Hicks-neutral technical change has the further characteristic of leaving relative income shares unchanged whereas Hicks' labor-using technical change raises labor's relative share and labor-saving technical changes do the opposite.

To characterize the effects of technical change in the production process, focuses are given on the innovation that causes a production function to shift, increasing the maximum output obtained from given endowment of inputs. Under equilibrium conditions, technical change can be measured by using the cost function as a dual to the production function.

The variation in equilibrium factor demand over time can be attributed to changes in output, changes in factor prices, and changes in the level of technology. If firms attempt to minimize the cost of producing the outputs, the equilibrium quantity of the factor input i is a function of the levels of outputs (Q), factor prices (W), and technology (T) as following

$$X_i = X_i(Q, W, T) \quad (13)$$

where $i = K, L, M$ and where Q is a vector of outputs, W a vector of factor prices, and T a technology index.

By total differentiation of equation (13) and algebraic manipulation, equation (14) can be written as

$$d \ln X_i = \sum_k \frac{\partial \ln X_i}{\partial \ln Q_k} d \ln Q_k + \sum_j \frac{\partial \ln X_i}{\partial \ln W_j} d \ln W_j + \frac{\partial \ln X_i}{\partial \ln T} d \ln T \quad (14)$$

The three terms on the right-hand side of equation (14) give, respectively, that part of the growth of input demand due to: a) variations in output levels with others being constant; the output effect, b) variations in factor prices with others held constant; the total substitution effect, and c) technical change with others constant; the technical change effect. The variation in the factor input level due to output and total substitution effect is calculated using the estimates of the parameters of the translog cost function.⁹⁾ The effect of technical change is calculated as a residual.

The Hickian definition of technical change bias indicates that technical change is X_i -saving (X_i -using) if, at constant relative factor price ratio, X_i/X_j decreases (increases). In general $d \ln X_i/X_j = d \ln X_i - d \ln X_j$, so that the actual growth in factor input ratios can be calculated as

$$d \ln \frac{X_i}{X_j} = \ln \frac{X_{i,t+n}}{X_{i,t}} - \ln \frac{X_{j,t+n}}{X_{j,t}}, \quad i = j$$

9) The cost share of factor inputs is given by

$$\begin{aligned} S_i &= \frac{\partial \ln C}{\partial \ln W_i} = \frac{W_i K_i}{C} \quad \text{Hence } W_i = \frac{C \cdot S_i}{K_i} \quad \text{or } \ln X_i = \ln C + \ln S_i - \ln W_i, \\ \frac{\partial \ln X_i}{\partial \ln Q_k} &= \frac{\partial \ln C}{\partial \ln Q_k} + \frac{\partial \ln S_i}{\partial \ln Q_k} - \frac{\partial \ln W_i}{\partial \ln Q_k} = R_k + \frac{\partial S_i}{S_i \partial \ln Q_k} \quad \text{since } W_i \text{ is constant.} \\ &= \frac{1}{S_i} (R_k S_i + \frac{\partial S_i}{\partial \ln Q_k}) \\ \frac{\partial \ln X_i}{\partial \ln W_j} &= \frac{\partial \ln C}{\partial \ln W_j} + \frac{\partial \ln S_i}{\partial \ln W_j} - \frac{\partial \ln W_i}{\partial \ln W_j} = \frac{1}{S_i} (X_j S_i + \frac{\partial S_i}{\partial \ln W_j}) \quad \text{for } i \neq j \\ \frac{\partial \ln X_i}{\partial \ln W_i} &= \frac{1}{S_i} (X_i S_i - S_i + \frac{\partial S_i}{\partial \ln W_i}) \quad \text{for } i = j \end{aligned}$$

Further, from equation (14), we obtain the following:

$$d \ln \frac{X_i}{X_j} dw_j = 0 = \frac{\partial \ln X_i}{\partial \ln T} d \ln T - \frac{\partial \ln X_j}{\partial \ln T} d \ln T \quad (15)$$

Then technical change is X_i -saving or X_i -using according to whether the right-hand side of (15) is negative or positive. Binswanger (1974b) generalized the definition of technical change bias to n inputs, which technical change is X_i -saving or X_i -using according to whether the cost share of X_i decreases or increases at unchanged relative input prices. In this framework it can be shown that:

$$d \ln s_i^* = \frac{\partial \ln X_i}{\partial \ln T} d \ln T - \frac{\partial \ln X_j}{\partial \ln T} d \ln T$$

and then technical change is X_i -saving or X_i -using according to whether $d \ln s_i^*$ is negative or positive.

III. Data Description

For estimation we require annual time series of GNP, national income, revenue shares, cost shares, quantity indices of outputs, price indices of inputs and index of technical progress. Values for these series were calculated for each country from 1964 to 1983, and scaled to 1 in 1975 for Korea and Japan, and in 1976 for Taiwan. The results are invariant to the scaling of the regressors.

Cost of labor services includes compensation to employees and the portion of income from unincorporated enterprises which was calculated by multiplying income from unincorporated enterprises by the ratio of compensation to employees to the rent, profit and interest from capital services. Cost of capital services is equal to capital compensation (national income less labor cost). The cost of imports is shown in GNP statistics.

The revenue share of each output and the cost share of each input is obtained by dividing the revenue from each output and the cost of each input by national income, respectively. Output quantity indices of the three outputs and imports price index can be calculated by using the national product accounting statistics at current and constant prices.

The quantity index of labor is constructed from the data of total persons employed. The price index of labor services is obtained by

dividing labor compensation by the number of persons employed. The price of capital service is obtained by dividing capital compensation by the net capital stock. The net capital stock only for Korea was adjusted for rates of capacity utilization which is available for Korea.

IV. Empirical Results

By using equation (7), the parameters of the translog cost function with the maintained hypothesis, and with Hicks' non-neutral technical change were estimated and used in the test of the separability hypothesis, in the calculation of elasticities, and in the decomposition analysis of technical change.

Initially, the parameter estimates of the translog cost function with the restrictions of symmetry, linear homogeneity of the cost function in input prices, and linear homogeneity of the production in inputs are referred as unconstrained estimates shown in Column I of Tables 1, 2 and 3 for Korea, Japan and Taiwan, respectively.

The parameter estimates of the cost function with input-output separability is presented in Column 2 of Tables 1, 2 and 3. The test is performed by calculating the maximum likelihood ratio (λ) or in logarithmic form $\ln \lambda = \ln L(\omega) - \ln L(\Omega)$. The test results for Korea, Japan and Taiwan present $\chi^2 = 33.51, 30.67$ and 71.25 which exceed 1% critical value 13.28 . We therefore reject the hypothesis of the input-output separability for three countries.

The rejection of the existence of input-output separability implies that changes in output composition will affect the cost-minimizing input mix for a given output level and thus affect the relative demand for inputs. In other words, a consistent index of aggregate output does not exist and cannot be used for estimating demand for inputs. This result is consistent with Burgess' results for the U.S.A., but is different from Mohabbat (1984) for India. The differing lengths of the same periods covered and the different data may provide a partial explanation for the difference between Mohabbat and this study.

For testing the hypotheses of linear separability for Korea, table 1 lists the parameter estimates, the restrictions, and the log of likelihood function. $\chi^2 (14.04)$ for linear separability between primary factors (K, L) and imports (M). $\chi^2 (17.91)$ for linear separability between (K, M) and L, and $\chi^2 (11.11)$ for linear separability between (M, L) and K exceed 1% critical value 9.21 . We therefore reject the hypothesis at 1% level of sig-

[Table 1] Parameter Estimates of Translog Cost Function with Input-Output Separability, and Linear and Nonlinear Separability for Korea

Constraints Parameters	none	Input-Output Separability		Linear Separability		Non-linear Separability	
		(K,L)	M	(K,L) and M	(L,M) and L	(K,L) and M	(K,M) and L (L,M) and K
α_K	.240 (.112.64)	.241 (.123.36)	.243 (.141.14)	.236 (.137.45)	.235 (.112.52)	.232 (.115.24)	$1 + \frac{\delta_{KM}}{\delta_{MM}} \alpha_M$
α_M	.312 (.70.18)	.297 (.41.96)	.295 (.64.71)	.294 (.79.90)	.317 (.66.11)	.332 (.69.99)	.301 (.39.81)
β_C	.578 (.198.82)	.594 (.188.66)	.581 (.220.28)	.582 (.209.52)	.580 (.219.4)	.595 (.142.53)	.586 (.136.61)
β_X	.215 (.93.74)	.205 (.93.23)	.214 (.90.25)	.212 (.90.90)	.213 (.98.31)	.206 (.76.90)	.208 (.71.42)
δ_{KK}	.383 (.5.55)	.041 (.7.42)	.034 (.5.89)	$-\delta_{KM}$	0	.013 (.6.95)	$\delta^2_{KM}/\delta_{MM}$
δ_{MM}	.104 (.5.80)	.007 (.3.0)	0	$-\delta_{KM}$	.106 (.6.47)	$\delta^2_{KM}/\delta_{KK}$	$\frac{\delta_{KM}}{\delta_{MM}}$
θ_{KM}	-.018 (-2.20)	-.015 (-2.03)	0	-.037 (-5.70)	0	-.039 (-4.81)	.012 (1.02)
θ_{CC}	.280 (.15.79)	.168 (.8.59)	.262 (.15.14)	.265 (.14.86)	.277 (.16.24)	.223 (.9.70)	.184 (10.41)
θ_{XX}	.178 (.21.81)	.143 (.16.48)	.176 (.21.21)	.171 (.20.01)	.213 (.98.31)	.152 (.18.26)	.158 (15.04)
ρ_{CS}	-.142 (-14.59)	-.078 (-7.21)	-.135 (-14.00)	-.132 (-13.18)	-.141 (-14.62)	-.102 (-8.99)	-.111 (-9.08)
ρ_{KC}	.004 (.54)	0	-.004 (-.59)	.004 (.54)	.003 (.46)	.044 (12.76)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MC}$
ρ_{KX}	-.007 (-1.29)	0	-.004 (-.68)	-.010 (-1.63)	-.017 (-2.91)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MX}$	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MK}$
ρ_{MC}	-.106 (-8.54)	0	-.080 (-6.63)	-.086 (-7.21)	-.099 (-8.14)	$\frac{\delta_{KM}}{\delta_{KK}} \cdot \rho_{KC}$	-.010 (-1.01)
ρ_{MX}	.070 (8.39)	0	.061 (6.64)	.056 (6.50)	.073 (8.51)	$\frac{\delta_{KM}}{\delta_{KK}} \cdot \rho_{KX}$	.023 (2.36)
γ_{Kt}	-.010 (-1.75)	-.014 (-4.33)	-.011 (-2.19)	-.016 (-2.86)	-.017 (-2.77)	$\frac{\delta_{KM}}{\delta_{KK}} \cdot \gamma_{Mt}$	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \gamma_{Mt}$
γ_{Mt}	.025 (2.43)	.077 (7.48)	.012 (1.14)	.007 (.76)	.036 (3.43)	$\frac{\delta_{KK}}{\delta_{KM}} \cdot \gamma_{Kt}$	.065 (7.51)
γ_{Ct}	.056 (5.45)	.007 (.50)	.049 (5.13)	.051 (5.13)	.056 (5.76)	.045 (3.54)	.014 (1.26)
γ_{Xt}	-.053 (-7.41)	-.027 (-2.87)	-.050 (-7.21)	-.050 (-7.16)	.054 (-7.41)	-.042 (-5.40)	-.042 (-5.08)
Log of Likelihood Function	290.354	273.597	283.335	281.598	284.799	281.609	241.891

(t values parentheses)

[Table 2] Parameter Estimates of Translog Cost Function with Input-Output Separability, and Linear and Nonlinear Separability for Korea

Constraints Parameters	none	Input-Output Separability			Linear Separability			Non-linear Separability		
		(K,L) and M	(K,M) and L	(L,M) and K	(K,L) and M	(K,M) and L	(L,M) and K	(K,L) and M	(K,M) and L	(L,M) and K
α_K	.171 (74.20)	.171 (64.18)	.175 (71.89)	.177 (49.91)	.189 (35.85)	.193 (27.61)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \alpha_M$	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \alpha_M$	$1 + \frac{\delta_{KM}}{\delta_{MM}} \cdot \alpha_M$	
α_M	.136 (83.80)	.137 (60.03)	.128 (40.82)	.138 (78.29)	.130 (47.81)	$1 + \frac{\delta_{KM}}{\delta_{KK}} \cdot \alpha_K$	.132 (38.91)	.121 (26.97)		
β_C	.606 (287.51)	.599 (266.00)	.608 (263.70)	.602 (290.78)	.606 (243.94)	.599 (297.17)	.603 (193.32)	.602 (210.00)		
β_X	.108 (55.05)	.115 (72.91)	.114 (64.72)	.118 (60.90)	.126 (37.22)	.119 (54.51)	.111 (51.68)	.114 (46.22)		
δ_{KK}	.107 (15.71)	.107 (16.80)	.085 (12.21)	$-\delta_{KM}$	0	.001 (1.73)	$\frac{\delta^2_{KM}}{\delta_{MM}}$	$\frac{\delta^2_{KM}}{\delta_{MM}}$		
δ_{MM}	.076 (9.58)	.137 (60.03)	0	$-\delta_{KM}$	.080 (6.72)	$\frac{\delta^2_{KM}}{\delta_{KK}}$	.003 (13.64)	.020 (10.80)		
θ_{CC}	.040 (8.00)	.041 (8.88)	0	-.063 (15.70)	0	-.006 (-1.74)	-.017 (-17.23)	.028 (15.94)		
θ_{XX}	.249 (19.18)	.162 (9.43)	.238 (19.26)	.228 (17.93)	.211 (16.13)	.157 (9.62)	.111 (5.72)	.132 (6.42)		
θ_{CX}	.095 (7.69)	.442 (4.77)	.036 (2.63)	.006 (.40)	-.042 (-1.89)	.038 (4.25)	.055 (4.45)	.039 (2.20)		
ρ_{KC}	.027 (2.78)	.011 (.93)	.032 (-3.35)	.004 (-.34)	.004 (-.31)	.026 (2.30)	.019 (1.41)	.027 (1.76)		
ρ_{KX}	.020 (3.35)	0	.030 (4.88)	.007 (1.04)	.029 (-4.19)	-.004 (-.93)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MC}$	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MC}$		
ρ_{MC}	.027 (4.09)	0	.006 (.87)	-.022 (3.82)	.069 (7.68)	-.030 (2.95)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MX}$	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MX}$		
ρ_{MX}	.031 (4.52)	0	.007 (.91)	.047 (5.71)	-.036 (4.16)	$\frac{\delta_{KM}}{\delta_{KK}} \cdot \rho_{KC}$	.026 (10.40)	.032 (-14.79)		
γ_{KI}	.006 (.72)	0	.038 (4.44)	.026 (3.09)	.039 (4.14)	$\frac{\delta_{KM}}{\delta_{KK}} \cdot \rho_{KX}$	-.013 (-6.78)	.028 (6.60)		
γ_{KI}	.039 (5.99)	.049 (7.33)	.045 (6.99)	.011 (2.00)	.005 (.73)	.021 (2.59)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \gamma_{Mt}$	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \gamma_{Mt}$		
γ_{Mi}	.009 (2.03)	.003 (.64)	.003 (.54)	.011 (3.55)	.030 (4.32)	$\frac{\delta_{KM}}{\delta_{KK}} \cdot \gamma_{Kt}$	.009 (2.44)	.034 (5.83)		
γ_{Ci}	.010 (1.69)	.017 (3.02)	.011 (2.05)	.002 (.45)	.011 (2.23)	.002 (.33)	-.007 (-1.24)	-.029 (5.15)		
γ_{Xi}	.001 (.01)	-.000 (.038)	.008 (1.72)	.003 (.53)	.016 (2.47)	.003 (.58)	.009 (2.27)	.026 (4.97)		
Log of Likelihood Function	317,336	302,001	302,383	304,931	289,677	271,637	316,780	299,898		

(t values parentheses)

[Table 3] Parameter Estimates of Translog Cost Function with Input-Output Separability, and Linear and Nonlinear Separability for Korea

Constraints	Parameters	none	Input-Output Separability		Linear Separability		Non-linear Separability		
			Separability		(K, L) and M	(K, M) and L	(L, M) and K	(K, L) and M	(K, M) and L (L, M) and K
									(t values parentheses)
	α_K	.197 (59.99)	.198 (59.31)	.211 (40.22)	.202 (69.05)	.230 (34.17)	.223 (50.62)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \alpha_M$	$1 + \frac{\delta_{KM}}{\delta_{MM}} \cdot \alpha_M$
	α_M	.380 (109.14)	.366 (43.12)	.366 (91.41)	.388 (97.89)	.348 (53.55)	$1 + \frac{\delta_{KM}}{\delta_{KK}} \cdot \alpha_K$	.374 (71.33)	.331 (42.87)
	β_C	.471 (147.49)	.461 (193.88)	.498 (91.88)	.474 (80.62)	.512 (68.70)	.498 (65.20)	.474 (119.24)	.486 (129.77)
	β_X	.327 (113.45)	.325 (194.55)	.293 (48.59)	.324 (57.39)	.278 (33.76)	.307 (44.90)	.317 (61.26)	.286 (47.13)
	δ_{KK}	.099 (15.67)	.102 (8.77)	.123 (5.53)	-. δ_{KM}	0	.034 (8.63)	$\frac{\delta^2_{KM}}{\delta_{MM}}$	$\frac{\delta^2_{KM}}{\delta_{MM}}$
	δ_{MM}	.185 (8.69)	.201 (2.69)	0	-. δ_{KM}	.135 (5.40)	$\frac{\delta^2_{KM}}{\delta_{KK}}$	.017 (7.07)	.070 (8.92)
	δ_{KM}	-.187 (-14.74)	-.090 (-3.52)	0	-.085 (-14.96)	0	-.096 (-8.95)	.036 (6.30)	.045 (9.88)
	θ_{CC}	.302 (19.00)	.294 (16.29)	.159 (20.06)	.130 (20.38)	.152 (21.27)	.118 (18.65)	.192 (25.62)	.225 (18.25)
	θ_{XX}	.217 (17.56)	.203 (23.33)	.467 (9.73)	.303 (5.80)	.334 (9.20)	.568 (8.65)	.301 (12.65)	.393 (18.27)
	θ_{CX}	-.088 (-10.72)	-.135 (-12.67)	-.212 (-9.91)	-.142 (-5.63)	-.145 (-9.04)	-.281 (-8.14)	-.134 (-10.76)	-.160 (-15.13)
	ρ_{KC}	.042 (6.48)	0	-.022 (-2.48)	.039 (4.60)	-.062 (-8.95)	.071 (20.66)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MC}$	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MC}$
	ρ_{KX}	-.018 (-2.91)	0	.039 (3.73)	-.025 (-3.42)	-.145 (-9.04)	-.373 (-8.27)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MX}$	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \rho_{MX}$
	ρ_{MC}	-.199 (-15.39)	0	-.141 (-8.09)	-.130 (-9.77)	-.130 (-9.11)	$\frac{\delta_{KM}}{\delta_{KK}} \cdot \rho_{KC}$	-.072 (-16.01)	-.046 (-9.73)
	ρ_{MX}	.066 (6.13)	0	.055 (2.88)	.012 (.71)	.063 (3.09)	$\frac{\delta_{KM}}{\delta_{KK}} \cdot \rho_{KX}$	.001 (.30)	.068 (4.95)
	γ_{Kt}	.059 (1.08)	-.012 (-2.24)	-.019 (-1.61)	.000 (.024)	-.085 (-9.87)	-.011 (-1.94)	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \gamma_{Mt}$	$\frac{\delta_{KM}}{\delta_{MM}} \cdot \gamma_{Mt}$
	γ_{Mt}	.097 (1.36)	.100 (5.86)	.021 (1.90)	.017 (1.89)	.068 (6.12)	$\frac{\delta_{KM}}{\delta_{KK}} \cdot \gamma_{Kt}$	.045 (11.15)	.098 (10.06)
	γ_{Ct}	.171 (2.10)	.041 (4.56)	-.040 (-4.02)	-.031 (-3.42)	-.082 (-8.28)	-.054 (-4.66)	-.012 (-2.41)	-.009 (-1.36)
	γ_{Xt}	-.029 (-4.04)	-.019 (-3.19)	.051 (5.27)	.027 (3.71)	.095 (9.18)	.040 (4.05)	.036 (6.30)	.068 (4.95)
Log of Likelihood Function		305.780	270.153	270.644	290.079	271.744	268.089	293.231	262.491

nificance. The χ^2 statistics calculated from Table 2 for Japan are 29.91 for (K, L) and M, 24.81 for (K, M) and L, and 55.32 for (L, M) and K. These exceed the critical value (9.21) for 1% level with 2 degrees of freedom, and we therefore reject the hypothesis. The χ^2 statistics calculated from Table 3 for Taiwan are 70.27 for (K, L) and M, 31.40 for (K, M) and L, and 68.07 for (K, M) and K. These also exceeds the critical value (9.21) for 1% level with 2 degrees of freedom. Therefore, we reject the hypothesis.

Since all the linear separability hypotheses for three countries are rejected, we proceed to test the non-linear separability hypotheses. The parameter estimates and the information needed for calculating χ^2 statistics for Korea are shown in Table 1. Likewise, χ^2 for (K, L) and M is 18.49, χ^2 for (K, M) and L 31.67, and χ^2 for (L, M) and K 96.93. Since the critical value at 1% level with 5 degrees of freedom is 15.09, the hypothesis is rejected at 1% level of significance.

From Table 2 for Japan, χ^2 for (K, L) and M is 91.4, χ^2 for (K, M) and L 1.11 and χ^2 for (L, M) and K 34.87. Except for (K, M) and L, the hypothesis is rejected at 1% level of significance. Table 3 for Taiwan gives that χ^2 for (K, L) and M is 75.38, χ^2 for (K, M) and L 25.10, and χ^2 for (L, M) and K 86.58. Since the critical value at 1% level with 5 degrees of freedom is 15.09, the hypothesis is also rejected at 1% level of significance.

The nonexistence of linear and nonlinear separability between each pair of inputs implies that the functional forms such as the Cobb-Douglas production function is not appropriate to describe the production technology of each country's economy. It further implies that it is inappropriate to specify import demand as a function of national output and the ratio of imports price and the price of domestic value added which is produced by domestic primary inputs. This result confirms that imports should be entered as an input into the production technology. Burgess (1974) and Mohabatt (1984) obtained similar results for the U.S. and India, respectively.

Table 4 shows the AES between each pair of inputs and the own price elasticities of demand for each input for Korea, Japan and Taiwan.

The results for Korea in Table 4 present that all inputs are substitutes for the period under study and own price elasticities of demand for inputs have theoretically appropriate negative sign and are inelastic. The results for Japan and Taiwan show that labor services and imports are substitutes as well as capital services and labor services for the period under study. However, capital services and imports are complements for Japan and Taiwan, and theoretically unexpected. Own price elasticities of demand for inputs in both countries have theoretically appropriate negative sign and are inelastic.

Our first observation of these results is the low elasticities of substitution between inputs. The elasticity of substitution measures the degree of responsiveness of industries in an economy to the changing availabilities of inputs. High elasticity of substitution implies that the production is flexible and the inputs released from one industry can be easily absorbed by other industries. Low elasticity of substitution implies that the economy can not easily absorb the inputs released from any industry. As Hong (1976) indicates, high elasticity of substitution means that a faster growing input can be substituted easily for a slower growing input. For most of the economies, especially developing economies, the capital stock grows much faster than the labor force, and the production technology become more capital intensive. High elasticity of substitution would enable the economy to accomplish this process without causing serious problems. On the other hand, low elasticity of substitution would bring about a growth in employment along with the accumulation of capital stock in case of full employment or an increase in wage rate. The low elasticities of substitution observed in these countries seem to be responsible for the increase in both employment and wage growth.

[Table 4] Elasticities of Substitution Between Inputs and Own Price Elasticities for Inputs

Country	Year	σ_{KL}	σ_{KM}	σ_{LM}	η_K	η_L	η_M
Korea	1965	.873	.597	.038	-.584	-.251	-.188
	1971	.845	.699	.287	-.597	-.282	-.324
	1977	.811	.757	.393	-.603	-.314	-.355
	1983	.783	.750	.445	-.609	-.317	-.353
Japan	1965	.531	-.713	.522	-.281	-.170	-.205
	1971	.578	-.593	.468	-.316	-.189	-.162
	1977	.445	-.797	.600	-.208	-.154	-.281
	1983	.388	-.737	.647	-.162	-.156	-.335
Taiwan	1965	.924	-.432	.083	-.369	-.502	-.084
	1971	.907	-.090	.234	-.365	-.569	-.076
	1977	.881	-.077	.351	-.335	-.588	-.127
	1983	.872	-.230	.395	-.298	-.561	-.128

Second, the figures indicate that capital and labor services are closer substitutes than other pairs of inputs for Korea and Taiwan. This seems to be a typical feature of a developing economy which is abundantly endowed with labor force, and, meanwhile, in the process of moving from the development of labor-intensive industries to the development of capital-intensive industries. This is especially true for those newly industrializing countries (NICS) such as Korea and Taiwan.

Third, The substitutability or complementability between domestic primary inputs and imports implies that trade barriers may have an important effect on domestic income distribution as Burgess (1974) has suggested. Suppose all inputs are substitutes and $\sigma_{KM} > \sigma_{LM}$ such as in Korea, then tariff barriers which raise the price of imports, will distribute income in favor of capital. Suppose labor services and imports are substitutes while capital services and imports are complements such as in Japan and Taiwan. This implies that domestic policies which raise user cost of capital services, will cause demand for imports to fall, and, in turn, will give favorable effect on balance of payments.

The key to the success of economic development in Korea, Japan and Taiwan is that they adopted export expansion policy instead of import substitution. As an open economy, imports of capital goods and raw materials become very important in developing export industries. This expansion of export industries has increased the capital intensity of their overall economies and has caused income to shift from labor to capital.

As far as trade policies are concerned, Korea, Japan and Taiwan have adopted trade policies which reduced trade barriers or even used duty-free measures to encourage the imports of capital goods and raw materials for the production of exportable goods. These free trade policies would contribute to distribute income in favor of labor services for Korea.

The coefficients of own price elasticities of demand for inputs measure the degree of responsiveness of input quantity demanded to a change in input prices. These coefficients are less than unity with negative sign. It is interesting to see that the demand for import is very inelastic in all three countries throughout the study period.

This would imply that the stability condition for foreign exchange market is not fulfilled, i.e., the depreciation of Korean won does not improve trade balance between Korea and Japan.

The imports of capital goods and raw materials are important and the need for these imports is very pressing. Due to this factor along with the favorable tariff policies to domestic producers, the price change in imports gave no great effect on demand for imports. However, the effect of price change has increased as the development of the economies of Korea and

Taiwan has reached a stage where the part of capital goods and even some materials would be supplied domestically.

An Analysis of Technical Change

The growth of equilibrium input demand is attributable to changes in output levels, changes in factor prices and technical change. The estimates of the decomposition are reported in Table 5 for Korea, Japan and Taiwan. Our results show that technical change effect is negative on input demand for all three economies. However, the magnitudes of these effects are different.

For Korean economy, capital demand annually increased by 13.1% for the period of 1964-83. The positive total effect on capital demand was largely due to positive substitution effects caused by a substantial increase in wage rate and imports price. The increases in wage rate and imports price caused capital demand to increase by 22.5% and 11.5% annually. This positive substitution effects reflecting the substitution relationship among inputs was reinforced by the positive output effect which are 4.6% for consumption goods, 2.3% for investment goods and 2.9% for exports.

The negative technical change effect implies that, due to technical progress, with unchanged input prices, a given output level could be produced by less input usage annually by 24.5% for capital, 20.5% for labor and 25.0% for imports.

In case of Japan, capital demand annually increased by 11.2% during the period of 1964-83 and the positive substitution effects were dominant. The own substitution effect on capital demand was positive for the periods of 1964-83 since the price of capital decreased during the periods. This decrease in capital price resulted in the opposite signs for the effects on labor and imports, and weakened the positive substitution effect on labor demand and imports demand. The major source of the positive effect on labor was the substitution effect caused by the increase in imports price and this was reinforced by the positive output effect. The positive substitution effect on imports caused by the increase in wage rate is also dominant and this was reinforced by the positive output effect. The positive substitution effects on input demand were negative. However, the magnitude of negative technical change effect is smaller in Japan than in Korea.

For Taiwan, the positive total effect on capital demand was largely due to a positive substitution effect caused by a increase in wage rate. This positive substitution effect was reinforced by the output effect. However the output effects on the demand for labor and imports are relatively much larger in Taiwan than those in Korea and Japan. Also, technical change

[Table 5] Decomposition of Growth in Input Demand for 1964-83

Input	Demand	Output Effect				Substitution Effect				Annual growth rate over the period	
		Q _c		Q _i		Q _x		W _k		W _m	
		$\frac{\partial \ln X_K}{\partial \ln Q_C}$	$\frac{\partial \ln X_K}{\partial \ln Q_I}$	$\frac{\partial \ln X_K}{\partial \ln Q_I}$	$\frac{\partial \ln X_K}{\partial \ln Q_X}$	$\frac{\partial \ln X_K}{\partial \ln W_K}$	$\frac{\partial \ln X_K}{\partial \ln W_L}$	$\frac{\partial \ln X_K}{\partial \ln W_M}$	$\frac{\partial \ln X_K}{\partial \ln W_L}$	$\frac{\partial \ln X_K}{\partial \ln W_M}$	Technical Change Effect
Capital	$\ln \frac{X_K, t+n}{X_K, t}$										
Korea	.131	.046	.023		.029	-.066	.225	.115			$\frac{\partial \ln X_K}{\partial \ln T}$
Japan	.112	.039	.002		.030	.000	.048	.046			-.245
Taiwan	.113	.049	.009		.031	-.010	.112	.044			-.057
Labor	$\ln \frac{X_L, t+n}{X_L, t}$										
Korea	.052			$\frac{\partial \ln X_L}{\partial \ln Q_I}$	$\frac{\partial \ln X_L}{\partial \ln Q_X}$	$\frac{\partial \ln X_L}{\partial \ln W_K}$	$\frac{\partial \ln X_L}{\partial \ln W_L}$	$\frac{\partial \ln X_L}{\partial \ln W_M}$			$\frac{\partial \ln X_L}{\partial \ln T}$
Japan	.011	.058	.011		.011	.153	-.086	.104			-.205
Taiwan	.035	.037	.006		.029	-.001	-.013	.057			-.107
Imports	$\ln \frac{X_M, t+n}{X_M, t}$										
Korea	.176			$\frac{\partial \ln X_M}{\partial \ln Q_I}$	$\frac{\partial \ln X_M}{\partial \ln Q_X}$	$\frac{\partial \ln X_M}{\partial \ln W_K}$	$\frac{\partial \ln X_M}{\partial \ln W_L}$	$\frac{\partial \ln X_M}{\partial \ln W_M}$			$\frac{\partial \ln X_M}{\partial \ln T}$
Japan	.071	.014	.042		.103	.149	.167	-.053			-.250
Taiwan	.140	.019	.038		.007	-.000	.059	-.035			-.017
		.011	.073		.082	.029	.070	-.048			-.084

[Table 6] Changes in Factor Combination Ratio and Biased Technical Change for 1964-83

	Country	Actual Growth	Technical Change	Technical Change Bias	
X_K	Korea	.079	-.040	K-saving	L-using
	Japan	.101	.050	K-using	L-saving
X_L	Taiwan	.078	.027	K-using	L-saving
X_K	Korea	-.027	.005	K-using	M-saving
	Japan	.041	-.040	K-saving	M-using
X_M	Taiwan	-.027	-.045	K-saving	M-using
X_L	Korea	-.105	.045	L-using	M-saving
	Japan	-.060	-.090	L-saving	M-using
X_M	Taiwan	-.105	-.072	L-saving	M-using

effect on input demand is negative as expected.

A more revealing approach to the analysis of the technical change effect is to examine its respective effect on capital and labor demand simultaneously. As already noted, the magnitudes of the negative technical change effects are different among inputs. This difference in the magnitudes can be used to obtain some further insights for judging the technical change bias. The results using the equation (15) shown in Table 6 show that technical change is labor-using and imports-saving for Korea for the periods of 1964-83. However, the results regarding capital are ambiguous; a negative sign of the technical change term for X_K/X_L implies labor-using and a positive sign for X_L/X_M implies imports saving.

For Japan, technical change is labor-saving and imports-using for the period of 1964-83. However, the results about capital are ambiguous. Technical change is labor-saving and imports-using for Taiwan. Similarly, the results for capital are unambiguous. This ambiguity results from the conventional Hicksian definition of biased technical change, which give unambiguous results only in the two-input case.

V. Summary and Conclusions

A dual cost function approach as well as a decomposition analysis have been used to estimate respectively the import demand functions and the effect of technical change on factor inputs for 1964-83 for Korea, Japan and Taiwan. We were interested in five major points:

(1) input-output separability (2) linear and nonlinear separability between imports and primary inputs (3) elasticity of substitution between inputs (4) price elasticities of input demand and (5) the effect of technical change on input demand and its biases.

We obtain the results which imply that imports should enter the production function as a factor input and that imports should not be treated as final goods. The results for Canada, the U.S.A., and India are similar to ours.

For all three economies, the hypothesis of input-output separability was rejected. This results implies that during the sample period changes in output mix would affect the relative demand for inputs. The rejection of linear and nonlinear separability of imports from primary inputs implies that the imports demand cannot be expressed as a function of the relative price of imports and aggregate output as conventionally proposed. Further, the rejection of the hypotheses of linear and nonlinear separability between inputs implies that Cobb-Douglas and CES functional forms cannot be suitable to represent the production technology of these economies.

All inputs have negative own price elasticities for all three countries and the demand for all inputs is inelastic. All inputs are substitute for each other in Korean economy and $\sigma_{KM} > \sigma_{LM}$, implying that an increase in import prices would redistribute income in favor of capital. For Japan and Taiwan, labor and imports as well as capital and labor are substitutes while capital and imports are complements. This results suggest that an increase in import prices would redistribute income in favor of labor.

According to the decomposition analysis, the total technical change effects on each input for three countries are negative, implying that a given output level could be produced by less input usage due to technical progress. A partial explanation for less input usage could be provided in terms of more efficient labor forces, and better quality of capital and raw material. By using the differences in the magnitudes of the technical change effect, calculation shows that technical change is labor-using and imports saving for Korea while it is labor saving and import using for Japan and Taiwan during the sample period.

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