

## **A Study on the Production Structure for the Japanese, Korean, and Taiwanese Manufacturing Industries: An Interrelated Factor Demand Model Approach\***

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In this paper, we analyze and compare the production structures of Japanese, Taiwanese and Korean manufacturing industries by estimating dynamic interrelated factor demand functions. Major findings are: first, the own-adjustment coefficient for capital market,  $M_{kk}$  is 0.53 for Japan, 0.41 for Taiwan and 0.30 for Korea, whereas that of skilled labor,  $M_{nn}$ , is 0.62 for Taiwan, 0.55 for Korea and 0.32 for Japan respectively. Second, capital and skilled labor turn out to be dynamic complements in all three countries. Third, in the short-run, distinct hoarding phenomena have been observed for all three countries' skilled labor market as well as capital market. Finally, Japanese manufacturing has shown positive rate of technical change but the other two countries have shown negative rates of technical change in the whole period.

### **I. Introduction**

For the last two decades, Korea has achieved remarkable level of economic development. One of the major factors for this success was the expansion of manufacturing industry, which was characterized by

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the reinforcement of industrial base and, the expansion of the employment opportunity. This characteristics of Korean experience was similar to those of Japan and Taiwan. Recently, Kuznets (1988) emphasized the needs to analyze these three countries' development experiences in a set of "East Asian Model," which can be characterized by high investment ratios, labor market competition, and export orientation. These three countries, however, differ in their development stages, particularly, in their industry structures, market sizes and trade dependences. Japan has highly competitive industrial structure through over a century's development endeavour and Taiwan has adopted different development strategies from Korea. Factor markets of these three countries, of course, have shown different behaviors and characteristics.

Japanese capital market experienced a drastic change after the first oil shock in 1973. Before that time, the capital market was always under excess demand condition. The price of capital was controlled by government to support the acceleration of the economic expansion. After the first oil shock, firms had to reduce outside loans and, at the same time, there emerged various types of financial instruments. Particularly, due to the establishment of the government bond market, the price mechanism of the capital market has been rapidly recovered.

Throughout 1980s, the financial liberalization and the globalization have been accelerated. Contrary to this, Taiwanese and Korean capital markets have been more segmented and distorted than Japanese capital market. In Taiwan, most banks were owned by government and managed relatively inefficiently. Most of loans from banks were short term loans and were inaccessible for the small businesses. Therefore, these small and medium sized firms, which are dominant in Taiwanese manufacturing sector, heavily depended upon the curb market with high capital cost. Due to this high capital cost, capital was allocated rather efficiently and was sensitive to the price changes even though the formal capital market was not fully developed in Taiwan.

As is indicated by Choi (1988), the Korean manufacturing sector, composed of relatively large firms, rapidly increased their investment mainly through the loans from banks. Korean government strongly controlled the capital market through the credit rationing and the interest cost differentials in favor of capital intensive sectors. This implies that the efficiency of the Korean capital market as a resource allocation mechanism has been significantly damaged.

There have been serious research interests on the Japanese manufacturing industries in comparison with US and other advanced Euro-

pean countries. However, we can hardly find any studies of empirically analyzing the behavior of Korean and Taiwanese manufacturing industries compared with that of Japan. In our previous study (Yung Joon Lee et al. 1991), however, we estimated employment functions of Japanese, Korean and Taiwanese manufacturing industries in the dynamic interrelated setup and compared the short run labor market adjustment and flexibility of those three countries. We found not only certain common characteristics, but also some unique features inherent in each economy: labor market hoarding phenomena were common for all three countries. The price elasticities of labor demand for these three countries concerned are much lower than those of US. On the other hand, Korean production labor market exhibited markedly high output elasticity compared with Japan and Taiwan, which means that, in Korea, production labor market absorbed substantial adjustment burdens of output fluctuations in the process of the rapid economic growth.

Since the role of investment and technology is critical in economic growth, our previous study on the labor market dynamics needs to be analyzed in connection with capital market dynamics and technical change in order to grasp the whole picture of production side dynamics of the economic growth. In this context, we extend our previous analysis to the whole production structure of those three countries' manufacturing industries, emphasizing the impact of technological change and short-run capital market adjustment and flexibility. More specifically, we need to empirically investigate the production structures and the characteristics of factor demands in each country to answer some important questions of the real economy: the monetary policy to lower the interest rate could induce the increase of investment and production, and thereafter this increases the employment opportunities, or how much the increase of real wage reduce the employment opportunity and so on.

Most of previous studies estimating the production structure and the factor demand functions of Korean manufacturing sectors adopted either specific functional forms (mostly CES function for Jang (1986) and Park et. al. (1986) or static translog models (Choi (1987) and Nam (1990)). As is pointed by Morrison and Berndt (1981), these econometric specifications on short-run relationship were largely based on ad hoc models with constant and exogenous partial adjustment assumptions. Therefore, we need to introduce the dynamic model, in which the adjustment of each factor to their long-run equilibrium is endogenous in the presence of adjustment cost of quasi-fixed factors.

In addition to this, as indicated by Nadiri and Rosen (1973), frequent output variations of the rapid growth, economies can cause substantial transaction costs for instantaneous adjustment in both labor and capital markets. Thus, most firms are never expected to remain along the equilibrium path at every point of time. Therefore, we can conjecture that the dynamic inter-market spillover effect, which is the cross effect of one factor market disequilibrium to the other, would be considerably high in the rapidly growing open economies like Japan, Korea and Taiwan.

For these purposes, we adopt dynamic interrelated factor demand model following the idea of Epstein and Yatchew (1983) and Mohen, Nadiri and Prucha (1986). In this model, the adjustment process of each factor is the outcome of firm's explicit dynamic optimization process, hence the adjustment speed of quasi-fixed factors to their long-run equilibrium is endogenous. It generates the short-run and long-run solutions for factor demands within a unified framework. Thus it enables us to calculate long-run elasticities as well as short-run elasticities. Moreover, since it allows two quasi-fixed factors, capital and skilled labor, to be interrelated both in the short-run and in the long-run, it is possible to estimate the inter-market spillover effects.

In section II, we briefly surveyed the historical unfolding of the econometric specification of the factor demand functions. Then, the basic model of this study is presented and two kinds of econometric specification is spelled out. One is three factor model, in which capital is the only quasi-fixed factor and labor and material are two variable factors. The other is four factor model with two quasi-fixed factors, capital and skilled labor and two variable factors, material and unskilled labor. Section III is about the empirical results of two types of model and their interpretation. Adjustment coefficients of quasi-fixed factors as well as own- and cross-price and output elasticities of factors are calculated. Also the degree of technical changes and biases of inputs are calculated and interpreted. In the concluding section, we summarized findings and their implications of this study and suggested directions for future study.

## II. The Model

Since 1960s there are many studies to analyse factor demands. Some of these studies have followed the Marshallian distinction between the short and long run.<sup>1</sup> Many economists have tried to incor-

<sup>1</sup> Berndt, E.R., Morrison, C.J. and G.C. Watkins (1981) emphasized that recent

porate this Marshallian framework into econometric models. These attempts to find out dynamic characteristics of factor demands are viewed to go through four generations.<sup>2</sup>

The first generation models are single equation models using the Koyck partial adjustment ideas. These lines of studies are assessed to be limited in that they neglect interactions among factors. An example of these studies is found in Balestra and Nerlove (1966).

The second generation models are more general than those of the first generation in that they introduce several inputs and analyze the interrelatedness of several factor demands. But these models are also restrictive because they do not consider explicitly the adjustment cost of quasi-fixed factors. These studies are found in Lucas (1967), Brechling and O'Brien (1967), Coen and Hickman (1970), Nadiri and Rosen (1969, 1973). The second generation approaches have some shortcomings such as the negligences of difference between fixed and variable factors, no information on the time path of adjustment from short to long run, and non-existence of the dynamic optimization.

The third generation models have several characteristics superior to the previous models. They consider explicitly the adjustment cost of quasi-fixed factors and formulate economic optimization process of a firm from the short run to the long run. These studies are found in Denny, Fuss and Wavermann (1981), Morrison and Berndt (1981), Nadiri and Prucha (1985), and Mohen, Nadiri and Prucha (1986). These models have several advantages to analyze interrelated factor demands, but have some limitations. These approaches are restrictive in that they are formulated and estimated under the static expectation on exogenous variables in the process of firms' optimization.

The fourth generation models consider non-static expectations on exogenous variables. They show that expectations have important roles in making decisions to reach the optimal states. The pioneering study is Pindyck and Rotemberg (1983 a). Other studies of this line are Epstein and Yatchew (1985), Pindyck and Rotemberg (1983 b), Kokkelenberg (1984), Kokkelenberg and Bischoff (1986) and Prucha and Nadiri (1986).

development of dynamic factor demand models enable applied researchers to incorporate dynamic optimization and to provide well-defined measures of adjustments for economic factors within the traditional Marshallian framework.

<sup>2</sup> For the explanation of dynamic factor demand model from the first to the third generation, see Berndt, Morrison and Watkins (1981) and for some arguments of the fourth generation model, see Kokkelenberg and Bischoff (1986).

Our model is formulated by specifying the system of the factor demand equations in discrete forms. Traditionally, most of papers which deal with dynamic factor demand build their models in the continuous form, consequently obtain their solutions specified in the form of differential equations, and then use a discrete linear approximation for empirical analyses.<sup>3</sup> These models have a limitation in that they should assume the separability of quasi-fixed factors for empirical applications.<sup>4</sup> Recently some discrete models have shown that the separability assumption of quasi-fixed factors can be relaxed.

This idea was initiated by Epstein and Yatchew (1985) and thereafter this has been modified in discrete models such as Mohen, Nadiri and Prucha (1986), Nadiri and Prucha (1985) and Prucha and Nadiri (1986). We adopt this idea to estimate the parameters of the dynamic interrelated factor demand model in non-separable forms. We assume the static expectation on exogenous variables.<sup>5</sup> We also assume that the manufacturing sector of a country behaves like a typical competitive firm, pursuing profit maximization. This firm uses  $m$  variable factors and  $n$  quasi-fixed factors in producing a single output and incurs the adjustment cost of quasi-fixed factors.

We assume that the firm's technology is described by the following general production function form.

$$(1) \quad y_t = F(v_t, x_{t-1}, \Delta x_t; T_t)$$

where  $y_t$  is output,  $v_t = (v_{1t}, v_{2t}, \dots, v_{mt})$ , is the vector of variable inputs, and  $x_t = (x_{1t}, x_{2t}, \dots, x_{nt})$ , is the vector of stocks of the quasi-fixed inputs at the end of period. The vector  $\Delta x_t \equiv x_t - x_{t-1}$  represents internal adjustment costs which bring about output diminution, and  $T_t$  is technology index, which is assumed to change uniformly according to time path, that is,  $T_t = t$ .

The firm's factor markets are assumed to be perfectly competitive.

<sup>3</sup> For the process of linear approximation in these dynamic factor demand models, see Treadway (1969, 1971, 1974) and Mortenson (1973).

<sup>4</sup> These types of papers are Denny, Fuss and Wavermann (1981), Morrison and Berndt (1981), Berndt, Morrison and Watkins (1981).

<sup>5</sup> It is very important to take into account firms' expectations on exogenous variables in the process of their decision making. Recent papers are emphasizing these aspects. But the assumption of non-static expectations requires additional number of parameter estimates. In particular, this study is dealing with the developing economies and has faced problem of degree of freedom because of data constraint, so we adopt the assumption of static expectations.

In this case we can describe production technology in terms of the normalized restricted cost function defined as  $G(w_t, x_{t-1}, \Delta x_t, y_t; t) = v_t$ , where  $v_{it}$ ,  $i = 1, 2, \dots, m$  denotes the cost-minimizing variable factors and  $w_t = (w_{2t}, w_{3t}, \dots, w_{mt})$  denotes the price vector, where  $w_{it}$  is the price of the  $i$ -th variable input  $v_{it}$  normalized by that of the first variable input  $v_{1t}$ . According to Lau (1976), the function  $G(\cdot)$  has the following properties:

- 1)  $G(\cdot)$  is decreasing in  $x_t$  and increasing in  $\Delta x_t$ ,  $w_t$  and  $y_t$ :  
 $\partial G / \partial x_i < 0$ ,  $\partial G / \partial \Delta x_i > 0$ ,  $\partial G / \partial w_j > 0$ ,  $\partial G / \partial y > 0$ ,  $i = 1, 2, \dots, n$ :  
 $j = 2, \dots, m$ .
- 2)  $G(\cdot)$  is concave in  $w_t$ .
- 3)  $G(\cdot)$  is convex in  $x_t$  and  $\Delta x_t$ .
- 4)  $\partial G(\cdot) / \partial w_{jt} = \hat{v}_{jt}$ ,  $j = 2, \dots, m$  the cost-minimizing factor level.<sup>6</sup>

In our empirical analysis we assume two kinds of models. The one is a three factor model with one quasi-fixed factor and two variable factors and the other is a four factor model with two quasi-fixed factors and two variable factors. In the three factor model, we take materials,  $m_t$  and labor,  $l_t$  as the first and second variable factors and stocks of capital,  $k_t$  as a quasi-fixed factor.  $w_t$  is then the real wage rate of labor normalized by the materials price. In the four factor model, we take materials,  $m_t$  and unskilled labor,  $l_t$  as the first and second variable factors and stocks of capital,  $k_t$  and stocks of skilled labor,  $n_t$  as the first and second quasi-fixed factor.<sup>7</sup>  $w_t$  is then the real wage rate of skilled labor normalized by materials price.<sup>8</sup>

As the three factor model is interpreted as a reduced model of the four factor model, we proceed our explanation of the model in terms of the latter. The functional form of  $G(\cdot)$  in our model is assumed to take the following form which has constant returns to scale technology.<sup>9</sup>

<sup>6</sup> This relation is Shepard' lemma.

<sup>7</sup> In the three factor model labor is measured in terms of stocks, but in the four factor model skilled labor and unskilled labor are measured differently. Skilled labor is measured in terms of stocks at the end of period and unskilled labor is measured in terms of men-hours. This is because we intend to follow the assumption that employment of skilled labor is fixed in the short run.

<sup>8</sup> For notational conveniences, we use  $w_t$  and  $l_t$  in both models, but note that the definitions of those variables are different.

<sup>9</sup> To change this four factor model into the three factor model, we have only to assume the following relations.

$$\alpha_n = \alpha_{nn} = \alpha_{kn} = \beta_{nn} = \beta_{kn} = \alpha_{wn} = \alpha_{nn} = \alpha_{ln} = 0$$

$$\alpha_n = \alpha_{wn} = \alpha_{nn} = \alpha_{nk} = \alpha_{kn} = \alpha_{ln} = 0$$

$$\begin{aligned}
 (2) \quad G(w_t, x_{t-1}, \Delta x_t, y_t, t) &= G(w_t, x_{t-1}/y_t, \Delta x_t/y_t, t)y_t \\
 G &= y_t(\alpha_0 + \alpha_w w_t + \alpha_{ww} w_t^2/2 + \alpha_{tw} w_t t + \alpha_t t) + \alpha_k k_{t-1} + \alpha_n n_{t-1} \\
 &\quad + \alpha_{kk}(k_{t-1}^2/y_t)/2 + \alpha_{nn}(n_{t-1}^2/y_t)/2 + \alpha_{kn} k_{t-1} n_{t-1}/y_t \\
 &\quad + \alpha_k \Delta k_t + \alpha_n \Delta n_t + g_{kk}(\Delta k_t^2/y_t)/2 + g_{nn}(\Delta n_t^2/y_t)/2 \\
 &\quad + g_{kn}(\Delta k_t \Delta n_t)/y_t + \alpha_{wk} w_t k_{t-1} + \alpha_{wn} w_t n_{t-1} + \alpha_{wk} w_t \Delta k_t \\
 &\quad + \alpha_{wn} w_t \Delta n_t + \alpha_{kk} k_{t-1} \Delta k_t + \alpha_{nn} n_{t-1} \Delta n_t + \alpha_{kn} k_{t-1} \Delta n_t \\
 &\quad + \alpha_{nk} n_{t-1} \Delta k_t + \alpha_{tk} k_{t-1} t + \alpha_{tn} n_{t-1} t + \alpha_{tk} \Delta k_t t + \alpha_{tn} \Delta n_t t
 \end{aligned}$$

From the total variable cost function  $G(\cdot)$ , we can separate the internal cost of adjustment as follows.

$$\begin{aligned}
 (3) \quad C(\Delta k_t, \Delta n_t) &= \alpha_k \Delta k_t + \alpha_n \Delta n_t + g_{kk}(\Delta k_t^2/y_t)/2 + g_{nn}(\Delta n_t^2/y_t)/2 \\
 &\quad + g_{kn}(\Delta k_t \Delta n_t)/y_t + \alpha_{wk} w_t \Delta k_t + \alpha_{wn} w_t \Delta n_t \\
 &\quad + \alpha_{kk} k_{t-1} \Delta k_t + \alpha_{nn} n_{t-1} \Delta n_t + \alpha_{kn} k_{t-1} \Delta n_t + \alpha_{nk} n_{t-1} \Delta k_t \\
 &\quad + \alpha_{tk} \Delta k_t t + \alpha_{tn} \Delta n_t t
 \end{aligned}$$

We assume that marginal adjustment costs of quasi-fixed factors are zero at a steady state, where  $\Delta k_t = \Delta n_t = 0$ .

$$\begin{aligned}
 (4-1) \quad \partial G/\partial \Delta k_t = \partial C/\partial \Delta k_t &= \alpha_k + g_{kk} \Delta k_t/y_t + g_{kn} \Delta n_t/y_t + \alpha_{wk} w_k \\
 &\quad + \alpha_{kk} k_{t-1} + \alpha_{nk} n_{t-1} + \alpha_{tk} t = 0
 \end{aligned}$$

$$\begin{aligned}
 (4-2) \quad \partial G/\partial \Delta n_t = \partial C/\partial \Delta n_t &= \alpha_n + g_{nn} \Delta n_t/y_t + g_{kn} \Delta k_t/y_t + \alpha_{wn} w_t \\
 &\quad + \alpha_{nn} n_{t-1} + \alpha_{kn} k_{t-1} + \alpha_{tn} t = 0
 \end{aligned}$$

At the stationary point, these conditions will be satisfied if and only if the following restrictions are imposed.

$$(5) \quad \alpha_k = \alpha_n = \alpha_{wk} = \alpha_{wn} = \alpha_{kk} = \alpha_{nn} = \alpha_{nk} = \alpha_{kn} = \alpha_{tk} = \alpha_{tn} = 0$$

We also assume  $g_{kn} = 0$ , which implies the separability in adjustment costs of quasi-fixed factors. In our model, we do not impose the restrictions  $\alpha_{kn} = 0$ , and therefore we assume non-separability of quasi-fixed factors.<sup>10</sup> We denote the real discount rate, the corporate tax

<sup>10</sup> This separability assumption is being employed in the models specified in continuous forms for empirical applications because in the process of solving this dynamic program-



rate, the depreciation rate of capital and the depreciation rate of unskilled labor as  $r_t$ ,  $u_t$ ,  $\delta_k$  and  $\delta_n$ .

The firm's objective is to find out input path such that the present value of future cost stream is minimized for given  $k_{t-1}$  and  $n_{t-1}$ , and subject to production technology (1). Under static expectation of exogenous variables, the firm's optimization problem at period  $t$  can be stated as follows.<sup>11</sup>

$$(6) \quad \min_{(k_{t+s}, n_{t+s})_{s=0}^{\infty}} \sum_{s=0}^{\infty} \{ [G(t+s) + q_{nt} I_{n, t+s}] (1 - u_t) + q_{kt} I_{k, t+s} \} (1 + r_t)^{-s}$$

where  $G(t+s) = G(w_t, k_{t+s-1}, n_{t+s-1}, \Delta k_{t+s}, \Delta n_{t+s}, y_t, t+s)$ ,<sup>12</sup> and  $q_{nt}$  and  $q_{kt}$  respectively the normalized acquisition price of skilled labor and capital.  $I_{n, t+s} = n_{t+s} - (1 - \delta_n) n_{t+s-1}$  and  $I_{k, t+s} = k_{t+s} - (1 - \delta_k) k_{t+s-1}$ . We assume  $\delta_n = 0$ .

The following set of Euler equation is necessary conditions to solve this dynamic programming problem.

$$(7) \quad -Bx_{t+s-1} + (A + (2 + r_t)B)x_{t+s} - (1 + r_t)Bx_{t+s-1} = a_t$$

$$\text{where } B = \begin{bmatrix} g_{kk} & 0 \\ 0 & g_{nn} \end{bmatrix}, \quad A = \begin{bmatrix} \alpha_{kk} & \alpha_{kn} \\ \alpha_{kn} & \alpha_{nn} \end{bmatrix}$$

$$\text{and } a_t = - \begin{bmatrix} \alpha_k + \alpha_{wk} w_t + \alpha_{tk} t + c_{kt} \\ \alpha_n + \alpha_{wn} w_t + \alpha_{tn} t + c_{nt} \end{bmatrix} y_t$$

with  $c_{kt} = q_{kt}(r_t + \delta_k)/(1 - u_t)$  and  $c_{nt} = q_{nt} r_t$ .

Treadway (1974) has shown that this type of solution can be interpreted as a flexible accelerator as follows.

$$(8) \quad \Delta x_t = M(x_t^* - x_{t-1}), \quad x_t^* = A^{-1} a_t, \quad M = \begin{bmatrix} m_{kk} & m_{kn} \\ m_{nk} & m_{nn} \end{bmatrix}$$

where  $x^* = [k^* \ n^*]'$  is the steady state solution of (6).

The matrix of adjustment coefficients  $M$  has to satisfy the following matrix equation.

ming problem they cannot lead to the explicit equations of endogenous variables to estimate the parameters of the models.

<sup>11</sup> In the three-factor model, we should put  $q_{nt}$  equal to zero.

<sup>12</sup> Under static expectations the current values of exogenous variables (at the period  $t$ ) are equal to future values of them (at the period  $t+s$ ,  $s = 1, 2, \dots, \infty$ ).

$$(9) \quad BM^2 + (A + r_i B)M - A = 0$$

In the three factor model,  $M$  implies  $m_{kk}$  and we can directly calculate  $m_{kk}$  as the following relation.

$$(10) \quad m_{kk} = ((-\alpha_{kk} + r_i g_{kk}) + \sqrt{(\alpha_{kk} + r_i g_{kk})^2 + 4\alpha_{kk}g_{kk}}) / (2g_{kk})$$

In the four factor model, we cannot get the explicit equations of  $m_{kk}$ ,  $m_{kn}$ ,  $m_{nn}$ , and  $m_{nk}$ . To solve this problem we define the matrix  $C$  as follows.

$$(11) \quad C = -BM = \begin{bmatrix} c_{kk} & c_{kn} \\ c_{kn} & c_{nn} \end{bmatrix}$$

Then we can express  $A$  and  $D$  in terms of  $B$  and  $C$ .<sup>13</sup>

$$(12) \quad A = C - (1 + r)[B - B(C + B)^{-1}B]$$

$$D = MA^{-1} = B^{-1} + (1 + r)(C - rB)^{-1} = \begin{bmatrix} d_{kk} & d_{kn} \\ d_{kn} & d_{nn} \end{bmatrix}$$

Substituting (12) and (13) into (9) we can write the demand equations for the quasi-fixed factors in the following forms.

$$(13) \quad k_t = d_{kk}a_{kt} = d_{kn}a_{nt} + (c_{kk}/g_{kk} + 1)k_{t-1} + (c_{kn}/g_{kk})n_{t-1}$$

$$(14) \quad n_t = d_{kn}a_{kt} + d_{nn}a_{nt} + (c_{kn}/g_{nn})k_{t-1} + (c_{nn}/g_{nn} + 1)n_{t-1}$$

For three factor model, we get the following  $k_t$  equation, using (8) and (10).

$$(15) \quad k_t = ((-\alpha_{kk} + r_i g_{kk}) + \sqrt{(\alpha_{kk} + r_i g_{kk})^2 + 4\alpha_{kk}g_{kk}}) / (2g_{kk}) \\ ((-1/\alpha_{kk})(\alpha_k + \alpha_1 w_1 + \alpha_{kt}t + c_k)y_t - k_{t-1})$$

We can derive the demand equations for two variable factors from the normalized restricted cost function. For the unskilled labor demand function, using Shephard's lemma, we have  $1_t = \partial G(t) / \partial w_l$ . For the materials, we have  $m_t = G(t) - w_l 1_t$  as a residual.

<sup>13</sup> For the derivation of these expressions (11) and (12), see Prucha and Nadiri (1986). This idea is similar to that of Epstein and Yatchew (1985). For the explicit expressions, see Nadiri and Prucha (1985) or the appendix of Mohen, Nadiri and Prucha (1986).

$$(16) \quad l_t = (\alpha_w + \alpha_{ww}w_t + \alpha_{rw}t)y_t + \alpha_{wk}k_{t-1} + \alpha_{wn}n_{t-1}$$

$$(17) \quad m_t = (\alpha_0 - \alpha_{ww}w_t^2/2 + \alpha_t t)y_t + \alpha_k k_{t-1} + \alpha_n n_{t-1} + \alpha_{kk}k_{t-1}^2/(2y_t) \\ + \alpha_{nn}n_{t-1}^2/(2y_t) + \alpha_{kn}k_{t-1}n_{t-1}/y_t + g_{kk}\Delta k_t^2/(2y_t) \\ + g_{nn}\Delta n_t^2/(2y_t) + \alpha_{tk}k_{t-1}t + \alpha_{tn}k_{t-1}t$$

In three factor model, we have to estimate the equations (15), (16) and (17) where the parameters related to skilled labor  $n$  are set to zero.

In the four-factor model, we have to estimate the four equations which consist of two equations (13) and (14), and two modified equations (16) and (17), where  $\alpha_{kk}$ ,  $\alpha_{nn}$ ,  $\alpha_{kn}$ ,  $d_{kk}$ ,  $d_{nn}$ , and  $d_{kn}$  are replaced by  $c_{kk}$ ,  $c_{kn}$ ,  $c_{nn}$ ,  $g_{kk}$ , and  $g_{nn}$ .

### III. Empirical Implementation

In this section we state briefly data sources and their construction and then present empirical results.

#### A. Data

The data that we use for empirical implementation of the production structures and factor demands are composed of the economic data about the total manufacturing sectors of Japan, Taiwan and South Korea. The data range from 1971 to 1985 for Japan, and from 1973 to 1987 for Taiwan and Korea.

Output, capital and materials are converted from current values into real variables using respective appropriate deflators. Labor is measured in terms of the number of workers existing at the end of each year. Unskilled labor is measured in terms of men-hours worked a year and skilled labor is measured in terms of the number of workers existing at the end of each year. For the empirical results to be comparable, we transform all data measured as monetary unit of each domestic currency into the data measured on a dollar base.

The sources and construction of our data are described in details in the appendix.

#### B. Empirical Results

##### 1) Estimated Coefficients

The estimation method of this model is full information maximum

likelihood (FIML) estimation method. For parameter computation we use the Davidson-Fletcher-Powell minimization technique in the software package of TSP, version 4.0.<sup>14</sup> When necessary, we have made corrections for the first-order autocorrelation of residual term.

The parameter estimates of our models are presented in Table 1 and 2. The fitting of the model are quite good in each country in that the values of  $R^2$ 's are all greater than 0.96. In the three factor model,

**Table 1**

**FULL INFORMATION MAXIMUM LIKELIHOOD PARAMETER ESTIMATES OF THE THREE-FACTOR MODEL FOR THE MANUFACTURING SECTORS OF JAPAN FOR 1971-1985 AND TAIWAN AND KOREA FOR 1973-1987<sup>a)</sup>**

Parameter	Japan		Taiwan		Korea	
$\alpha_0$	2.006	(2.563)	0.725	(13.445)	10.491	(3.893)
$\alpha_t$	0.064	(2.610)	0.035	(3.658)	0.0003	(0.083)
$\alpha_k$	-6.051	(-2.005)	-3.560	(-3.290)	-2.312	(-3.482)
$\alpha_l$	1.853	(6.081)	0.549	(13.051)	2.307	(19.565)
$\alpha_{kk}$	13.032	(2.218)	49.993	(2.813)	10.491	(3.893)
$g_{kk}$	2.284	(0.838)	28.222	(2.058)	24.683	(3.330)
$\alpha_{ll}$	-0.365	(-3.541)	-0.091	(-4.465)	-0.137	(-6.299)
$\alpha_{lk}$	-1.708	(-3.541)	-1.671	(-4.032)	-1.836	(-10.302)
$\alpha_{kt}$	-0.133	(-0.002)	-0.257	(-2.642)	0.016	(1.194)
$\alpha_{lt}$	-0.002	(-0.144)	0.001	(0.272)	0.034	(3.176)
log of LF <sup>b)</sup>	107.66		154.03		127.67	
	$R^2$	D-W	$R^2$	D-W	$R^2$	D-W
k equation	0.999	1.461	0.993	1.011	0.999	1.002
l equation	0.999	0.963	0.998	0.964	0.999	0.388
m equation	0.999	1.584	0.999	0.918	0.999	0.937

Notes: a)  $R^2$ 's are calculated as unity minus the ratio of the residual sum of squares to the total sum of squares. Asymptotic t-values are given in parentheses.

b) LF means likelihood function.

<sup>14</sup> There are three kinds of FIML numerical methods of TSP of version 4.1. It turns out that Davidson-Fletcher-Powell method is much slower than the other methods, Gauss method and Grad method, but provides stable converging estimates at any initial values of parameters.

Table 2

FULL INFORMATION MAXIMUM LIKELIHOOD PARAMETER ESTIMATES OF THE FOUR-FACTOR MODEL FOR THE MANUFACTURING SECTORS OF JAPAN FOR 1971-1985, AND TAIWAN AND KOREA FOR 1973-1987<sup>a)</sup>

Parameter	Japan		Taiwan		Korea	
$\alpha_0$	1.087	(4.832)	4.629	(4.009)	1.398	(7.881)
$\alpha_k$	-3.470	(-2.135)	3.396	(1.979)	-1.556	(-3.183)
$\alpha_n$	-1.000	(-3.029)	-11.127	(-4.115)	-0.480	(-0.897)
$c_{kk}$	-7.766	(-2.401)	-4.788	(-3.100)	-2.475	(-4.247)
$c_{kn}$	0.869	(1.698)	1.453	(1.220)	0.808	(1.976)
$c_{nn}$	-5.898	(-2.399)	-7.380	(-1.930)	-2.395	(-8.323)
$g_{kk}$	14.690	(1.607)	11.698	(1.491)	8.393	(3.650)
$g_{nn}$	18.345	(1.437)	11.846	(1.396)	4.339	(4.017)
$\alpha_w$	0.078	(2.127)	1.165	(3.168)	1.051	(13.139)
$\alpha_{ww}$	-0.056	(-1.965)	-0.159	(-1.705)	-0.027	(-1.063)
$\alpha_{wk}$	-0.166	(-4.740)	-1.345	(-4.156)	-0.741	(-8.470)
$\alpha_{wn}$	0.501	(7.428)	1.805	(4.007)	-0.372	(-4.852)
$\alpha_l$	0.145	(3.126)	0.102	(0.781)	0.021	(0.980)
$\alpha_{lw}$	0.005	(3.487)	0.030	(1.198)	0.032	(4.769)
$\alpha_{lk}$	-0.297	(-3.180)	-0.419	(-4.192)	0.086	(3.126)
$\alpha_{ln}$	-0.008	(-0.380)	0.226	(1.499)	-0.098	(-4.776)
log of LF <sup>b)</sup>	168.094		120.199		145.581	
	R <sup>2</sup>	D-W	R <sup>2</sup>	D-W	R <sup>2</sup>	D-W
k equation	0.996	0.881	0.993	0.987	0.996	0.978
n equation	0.995	0.943	0.991	0.624	0.993	1.245
l equation	0.996	1.107	0.991	0.281	0.965	0.755
m equation	0.981	1.160	0.979	0.878	0.993	1.023

Notes: a) R<sup>2</sup>'s are calculated as unity minus the ratio of the residual sum of squares to the total sum of squares. Asymptotic t-values are given in parentheses.

b) LF means likelihood function.

t-values of estimated coefficients in Korean and Taiwanese manufacturing sectors are mostly statistically significant, but Japanese model have relatively more insignificant coefficients than the other countries. In the four factor model, Taiwanese results have relatively insignificant coefficients in comparison with other two countries. Durbin-Watson statistics show that the autocorrelation of most estimated

equations are inconclusive, but some positive autocorrelation may be present in the equation such as unskilled labor equation of Taiwan. The important restrictions from the convexity of  $G(\cdot)$  in  $x_i$  and  $\Delta x_i$ , and concavity in  $w_i$  are all satisfied.<sup>15</sup>

## 2) Adjustment Speed

We can also derive adjustment coefficient estimates for  $m_{kk}$ ,  $m_{kn}$ ,  $m_{nk}$ , and  $m_{nn}$  from the estimates of Table 3 and Table 4.

**Table 3**

FIML ESTIMATES OF OWN ADJUSTMENT COEFFICIENTS OF CAPITAL IN THE THREE-FACTOR MODEL: SAMPLE AVERAGES<sup>a)</sup>

adjustment coefficients	Japan		Taiwan		Korea	
$m_{kk}$	0.855	(4.724)	0.687	(5.654)	0.435	(2.236)

Note: a) Asymptotic t-values are given in parentheses.

**Table 4**

FIML ESTIMATES OF OWN- AND CROSS-ADJUSTMENT COEFFICIENTS OF CAPITAL AND SKILLED LABOR IN THE FOUR-FACTOR MODEL FOR THE MANUFACTURING SECTORS OF JAPAN, TAIWAN AND KOREA: SAMPLE AVERAGES<sup>a)</sup>

adjustment coefficients	Japan		Taiwan		Korea	
$m_{kk}$	0.529	(3.694)	0.409	(2.495)	0.295	(3.516)
$m_{kn}$	-0.059	(-1.515)	-0.124	(-1.447)	-0.096	(-1.938)
$m_{nk}$	-0.047	(-2.085)	-0.123	(-2.502)	-0.186	(-2.685)
$m_{nn}$	0.322	(3.356)	0.623	(4.728)	0.552	(7.138)

Note: a) Asymptotic t-values are given in parentheses.

<sup>15</sup> In the three-factor model, these restrictions are  $\alpha_{kk} > 0$ ,  $\alpha_{nn} > 0$ ,  $g_{kk} > 0$ ,  $\alpha_{ww} < 0$  and in the four-factor model,  $\alpha_{kk} > 0$ ,  $\alpha_{nn} > 0$ ,  $\alpha_{kk}\alpha_{nn} - \alpha_{kn}^2 > 0$ ,  $g_{kk} > 0$ ,  $g_{nn} > 0$ ,  $\alpha_{ww} < 0$ .

Some interesting points are referred as follows. First, in the three-factor model, the own-adjustment coefficients of capital are 0.86, 0.69 and 0.44 for the Japanese, Taiwanese and Korean Manufacturings, respectively. On the other hand in the four-factor model capital adjustment coefficients are 0.53, 0.41 and 0.30 for the Japanese, Taiwanese and Korean manufacturings respectively. These figures are different in terms of magnitude, but the same in order.

Second, in Japan the own-adjustment coefficient for capital,  $m_{kk}$  is higher than the own-adjustment coefficient for skilled labor,  $m_{nn}$  but in Taiwan and Korea the reverse result is found. In Japan the own-adjustment coefficient for capital is higher by approximately 60% than that for skilled labor. From this result, we can interpret that the competitiveness of Japanese capital market leads to high adjustment speed as well as low adjustment cost whereas the adjustment of Japanese labor market shows the lowest due to life-time employment system and high level of human capital investment. Japanese labor market and high level of expenditures to human capital investment bring about lower speed of skilled labor. On the other hand, from the Taiwanese and Korean results, we can interpret that Taiwanese and Korean firms have payed much internal costs of adjustment for the capital because of high curb market interest in relatively large informal capital market and high search costs of capital in distorted dual capital market. Also the result shows that Korean own-adjustment coefficients of both capital and skilled labor are lower than Taiwanese corresponding coefficients.

Third, capital and skilled labor are dynamic complements in all three countries. The cross-adjustment coefficients,  $m_{kn}$  and  $m_{nk}$  are much lower in Japan than those in Taiwan and Korea. The values of  $m_{kn}$  are similar to those of  $m_{nk}$  in Japan and Taiwan, but the value of  $m_{nk}$  is twice as large as that of  $m_{kn}$  in Korea. From this, we can imagine that if capital is in excess demand in three countries, the adjustment in skilled labor market will slow down and vice versa. This implies that rapidly growing Japanese quasi-fixed factor markets have lower interactions between them than Korean and Taiwanese quasi-fixed factor market.

Since output variations of the high growth economies cause substantial transaction costs for instantaneous adjustment in both capital and labor markets, indicated by Nadiri and Rosen (1969, 1973), most firms are not expected to remain along the equilibrium path at every point of time. From this, we can expect that relatively rapidly growing open economies like Korea and Taiwan have higher cross ef-

fect than relatively stable economy like Japan.

### 3) Price and Output Elasticities

We distinguish between the short-run (SR), intermediate-run (IR) and long-run (LR) responses of inputs to the exogenous prices and quantity shocks. The short-run elasticities measure the first-period response, when the firm is adjusting its capital and skilled labor and consequently incurs the costs of adjustment, but operating with the initial levels of these stocks. The intermediate-run elasticities refer to the second period responses and the long-run elasticities refer to the responses after completion of adjustment process.

Various elasticities with respect to the unnormalized price of materials, unskilled labor, capital, skilled labor, and output, denoted as  $w_m$ ,  $w_l$ ,  $c_k$ ,  $c_n$  and  $y_t$  are calculated.

Let  $\hat{x}_{t+s} = (\hat{x}_{1,t+s}, \hat{x}_{2,t+s})$  with  $s = 1, 2, \dots, \infty$  be the optimal input sequence of the quasi-fixed factors defined by (8). Then we have

$$(19) \quad \hat{x}_t = Mx_t^* + (I - M)x_{t-1}, \quad \hat{x}_{t+1} = Mx_t^* + (I - M)x_t, \quad \hat{x}_{t+\infty} = x_t^*$$

We refer to the elasticities of  $\hat{x}_{jt}$ ,  $\hat{x}_{j,t+1}$ , the short-run, intermediate-run and long-run elasticities of the  $j$ -th quasi-fixed factors. We denote them  $\varepsilon_{x/z}^S$ ,  $\varepsilon_{x/z}^I$ , and  $\varepsilon_{x/z}^L$  where  $Z = w_m, w_l, c_k, c_n$  and  $y_t$ .

$$(20) \quad \begin{aligned} \varepsilon_{x/z}^S &= (\partial \hat{x}_{jt} / \partial z)(z / \hat{x}_{jt}) \\ \varepsilon_{x/z}^I &= (\partial \hat{x}_{j,t+1} / \partial z)(z / \hat{x}_{j,t+1}) \\ \varepsilon_{x/z}^L &= (\partial x_{jt}^* / \partial z)(z / x_{jt}^*) \end{aligned}$$

Let  $v_{t+s} = (\hat{v}_{1,t+s}, \hat{v}_{2,t+s})$  be the sequence of optimal variable inputs associated with  $\hat{x}_{t+s}$  for  $s = 1, 2, \dots$ . Let us write  $\hat{v}_{it}$ ,  $\hat{v}_{i,t+1}$  and  $v_{it}^*$  as the value of  $v_{it}$  in which  $\hat{x}_{t-1}^*$ ,  $\hat{x}_t^*$  and  $x_t$  are substituted for one argument  $x_{t-1}$  of  $v_{it}$  equation. Using  $\hat{v}_{it}$ ,  $\hat{v}_{i,t+1}$  and  $v_{it}^*$ , we calculate the short-run, intermediate-run and long-run elasticities of the  $i$ -th variable factors with respect to input prices and output defined as follows.

$$(21) \quad \begin{aligned} \varepsilon_{v/z}^S &= (\partial \hat{v}_{it} / \partial z)(z / \hat{v}_{it}) \\ \varepsilon_{v/z}^I &= (\partial \hat{v}_{i,t+1} / \partial z)(z / \hat{v}_{i,t+1}) \\ \varepsilon_{v/z}^L &= (\partial v_{it}^* / \partial z)(z / v_{it}^*) \end{aligned}$$

Since the quasi-fixed factors of this model do not adjust immedi-



ately to their long-run equilibrium values, some of the variable factors can overshoot in the short run. That is, the short-run elasticities of some variable factors can be larger than the long-run output elasticities.

Table 5 shows the own-price elasticities of capital labor, and materials for the three-factor model. Table 6 shows the own-price elasticities of the four-factor model. All elasticities have the expected negative sign in accordance with the concavity in factor prices. Several remarks need to be indicated.

First, in the three-factor model, the own-price elasticities of capital for the Korean manufacturing and Taiwanese manufacturing are highest among three countries. The four-factor model shows that the own-price elasticities of capital for the Korean manufacturing are a little high, which is consistent with the result of three-factor model.

Second, in the case of labor, the two models show the different results. The own-price elasticities of skilled and unskilled labor for the Taiwanese Manufacturing are relatively low, which is opposite to the three-factor model case. Third, the own-price elasticities of skilled and unskilled labor are highest in Japan. For the own-price elasticities of the unskilled labor, similar to the skilled labor, Taiwanese values are lowest. Those values of Japan and Korea are similar each other.

The cross-price elasticities among factors are shown in Table 7 and 8. We can find that across the board in the three-factor model, long run elasticities are low relative to those of intermediate run. But in the

Table 5

SHORT-RUN, INTERMEDIATE-RUN AND LONG-RUN OWN-PRICE ELASTICITIES IN THE THREE-FACTOR MODEL: SAMPLE AVERAGES<sup>a)</sup>

elasticity estimate	Japan			Taiwan			Korea		
	SR	IR	LR	SR	IR	LR	SR	IR	LR
$\epsilon_{kk}$	-0.13	-0.14	-0.15	-0.18	-0.22	-0.25	-0.16	-0.24	-0.35
$\epsilon_{ll}$	-0.12	-0.21	-0.05	-0.38	-0.63	-0.18	-0.02	-0.05	-0.03
$\epsilon_{mm}$	-0.09	-0.12	-0.06	-0.16	-0.16	-0.13	-0.14	-0.17	-0.00

Note: a)  $\epsilon_{ii} \equiv (\partial x_i / \partial c_i)(c_i / x_i)$ , where  $x_i$  is a  $i$ -th quasi-fixed factor and  $c_i$  is the user cost of  $x_i$  and  $\epsilon_{jj} \equiv (\partial v_j / \partial w_j)(w_j / v_j)$ ,  $j = 1, m$ , where  $v_j$  is a  $j$ -th variable factor and  $w_j$  is the price of  $v_j$ .

**Table 6**  
**SHORT-RUN, INTERMEDIATE-RUN AND LONG-RUN OWN-PRICE ELASTICITIES IN THE FOUR-FACTOR MODEL: SAMPLE AVERAGES<sup>a)</sup>**

elasticity estimate	Japan			Taiwan <sup>b)</sup>			Korea <sup>c)</sup>		
	SR	IR	LR	SR	IR	LR	SR	IR	LR
$\epsilon_{kk}^{a),b)}$	-0.12	-0.17	-0.24	-0.29	-0.50	-0.98	-0.34	-0.26	-1.06
$\epsilon_{nn}^{d)}$	-0.33	-0.56	-1.08	-0.10	-0.15	-0.20	-0.36	-0.53	-0.78
$\epsilon_{ll}^{d)}$	-0.42	-0.65	-1.15	-0.12	-0.30	-0.50	-0.05	-0.45	-1.23
$\epsilon_{mm}$	-0.06	-0.48	-1.28	-0.15	-0.74	-2.00	-0.04	-0.24	-0.46

Notes: a) For the range of 1970s and 1980s period of three countries, see the Table 4, footnote a).

$\epsilon_{ii} \equiv (\partial x_i / \partial c_i)(c_i / x_i)$ ,  $i = k, n$ , where  $x_i$  is a  $i$ -th quasi-fixed factor and  $c_i$  is the user cost of  $x_i$ , and  $\epsilon_{jj} \equiv (\partial v_j / \partial w_j)(w_j / v_j)$ ,  $j = l, m$ , where  $v_j$  is a  $j$ -th variable factor and  $w_j$  is the price of  $v_j$ .

b) For the intermediate-run elasticity estimates of Taiwanese manufacturing, 1974's values are excluded.

c) The averages of Korean long-run elasticities estimates are calculated, excluding the estimates over the period 1973-1976 because those values are very unstable and the averages over total period may be misleading.

**Table 7**  
**SHORT-RUN, INTERMEDIATE-RUN AND LONG-RUN CROSS-PRICE ELASTICITIES IN THE THREE-FACTOR MODEL: SAMPLE AVERAGES**

elasticity estimate	Japan			Taiwan			Korea		
	SR	IR	LR	SR	IR	LR	SR	IR	LR
$\epsilon_{kl}^{a)}$	0.03	0.04	0.04	0.21	0.25	0.29	0.10	0.15	0.22
$\epsilon_{km}$	-0.21	-0.22	-0.04	-0.24	-0.29	-0.29	-0.38	-0.54	-0.22
$\epsilon_{lk}$	0.00	0.08	-0.30	0.00	0.00	-0.22	0.00	0.09	-0.09
$\epsilon_{lm}$	0.12	0.53	0.14	0.38	0.64	0.48	0.02	0.11	0.03
$\epsilon_{mk}$	-0.01	-1.88	0.03	-0.01	-7.34	0.01	-0.03	0.18	0.11
$\epsilon_{ml}$	0.08	0.09	0.07	0.16	0.16	0.13	0.09	0.10	0.00

Note: a)  $\epsilon_{ij} \equiv (\partial i / \partial j)(j / i)$ , where  $i = k, l$  and  $m$ , and  $j = C_k, W_l$  and  $W_m$ .

four-factor model, most of elasticities are larger than those of intermediate run except a few. Some other characteristic points are as follows.

**Table 8**  
**SHORT-RUN, INTERMEDIATE-RUN AND LONG-RUN CROSS-PRICE ELASTICITIES: SAMPLE AVERAGES**

elasticity estimate	Japan			Taiwan			Korea <sup>a)</sup>		
	SR	IR	LR	SR	IR <sup>c)</sup>	LR	SR	IR	LR
$\epsilon_{kn}^b$	-0.03	-0.05	-0.10	-0.07	-0.13	-0.26	-0.12	-0.22	-0.52
$\epsilon_{kl}$	0.00	0.00	-0.02	0.15	0.23	0.38	0.28	0.48	0.99
$\epsilon_{km}$	0.14	0.22	0.06	0.21	0.39	-0.44	0.19	0.32	-0.04
$\epsilon_{nk}$	-0.07	-0.12	-0.29	-0.08	-0.15	-0.28	-0.23	-0.42	-0.81
$\epsilon_{nl}$	-0.16	-0.27	-0.51	-0.08	-0.09	-0.05	0.29	0.48	0.89
$\epsilon_{nm}$	0.55	0.95	1.87	0.26	0.38	0.54	0.29	0.46	0.69
$\epsilon_{lk}$	0.00	0.01	-0.16	0.00	0.10	0.26	0.00	0.44	1.25
$\epsilon_{ln}$	0.00	-0.40	-1.35	0.00	-0.04	-0.04	0.00	0.25	0.74
$\epsilon_{lm}$	0.42	1.04	2.96	0.12	0.25	1.22	0.05	-0.24	-0.16
$\epsilon_{mk}$	0.00	0.14	0.36	0.00	0.22	0.67	0.00	0.21	0.92
$\epsilon_{mn}$	0.00	0.20	0.77	0.00	0.21	0.58	0.00	0.19	0.68
$\epsilon_{ml}$	0.06	0.15	0.42	0.15	0.31	0.51	0.04	-0.16	-0.87

Notes: a) For the excluded period in calculating Korea's long-run elasticities, see Table 5, footnote b).

b)  $\epsilon_{ij} \equiv (\partial i / \partial j)(j/i)$ , where  $i = k, n, l$  and  $m$ , and  $j = C_k, C_n, W_l$  and  $W_m$ .

c) These intermediate-run elasticity estimates are averaged from the elasticity estimates over the period 1974-1987.

First, capital and skilled labor are complementary factors, but materials and skilled labor are substitutable factors in all three countries whereas, labor and materials of all countries are substitutes in both models. Second, skilled and unskilled labor of Japan and Taiwan are complements, while those of Korea are substitutes. Third, it is interesting that the responses to capital are very low in the three-factor models of three countries and also the same phenomenon happens in unskilled labor of the four-factor model. But the responses of skilled labor to capital price are relatively high in all three countries. Therefore the effects of capital price on the labor in three countries are considerably low. Finally, the effects of materials price upon the other factors are roughly higher than the other effects in both models for all three countries.

Table 9 and 10 show the output elasticities of factors. The long-run elasticities of all factors equal to unity, as implied by the underlying

linear homogenous technology. Some points are worthwhile to mention.

**Table 9**  
SHORT-RUN, INTERMEDIATE-RUN AND LONG-RUN OUTPUT  
ELASTICITIES IN THE THREE-FACTOR MODEL: SAMPLE AVERAGES

elasticity estimate	Japan			Taiwan			Korea		
	SR	IR	LR	SR	IR	LR	SR	IR	LR
$\epsilon_{ky}$ <sup>a)</sup>	0.88	0.93	1.00	0.74	0.86	1.00	0.47	0.69	1.00
$\epsilon_{ly}$	2.63	1.25	1.00	1.64	1.22	1.00	1.23	0.90	1.00
$\epsilon_{my}$	6.33	0.97	1.00	1.75	1.00	1.00	1.75	0.90	1.00

Note: a)  $\epsilon_{iy} \equiv (\partial i / \partial y)(y/i)$ , where  $i = k, n, l$  and  $m$ .

**Table 10**  
SHORT-RUN, INTERMEDIATE-RUN AND LONG-RUN OUTPUT  
ELASTICITIES IN THE FOUR-FACTOR MODEL: SAMPLE AVERAGES<sup>a)</sup>

elasticity estimate	Japan			Taiwan			Korea		
	SR	IR	LR	SR	IR	LR	SR	IR	LR
$\epsilon_{ky}$ <sup>b)</sup>	0.43	0.75	1.00	0.27	0.47	1.00	0.24	0.46	1.00
$\epsilon_{ny}$	0.18	0.41	1.00	0.43	0.72	1.00	0.31	0.51	1.00
$\epsilon_{ly}$	0.51	0.43	1.00	0.74	1.03	1.00	2.20	2.06	1.00
$\epsilon_{my}$ <sup>c)</sup>	2.11	2.07	1.00	1.59	3.91	1.00	1.74	2.63	1.00

Notes: a) For the range of the respective periods, see Table 4, footnote a).

b)  $\epsilon_{iy} \equiv (\partial i / \partial y)(y/i)$ , where  $i = k, n, l$  and  $m$ .

c) For the intermediate-run elasticity estimates of Taiwanese sectors, the annual estimates from 1973 to 1976 are excluded in the process of averaging because of the unstability of them.

First, in the three-factor model there are overshooting in material and labor markets, but undershooting in capital market responding to output variations. In Korea, there is a larger undershooting of capital compared with other two countries. This phenomena seem to be closely related to the low own-adjustment speed of capital in Korean manu-

facturing sector. Second, in the four-factor model, short-run and intermediate-run output elasticities of two quasi-fixed factors, capital and skilled labor are below unity, which means that those factors are slow in adjusting to their long-run equilibrium value. In other words, there exists increasing returns to scale in using the two quasi-fixed factors.

Third, from the finding that output elasticities of materials are above unity in three countries, we can indicate that materials respond sensitively to output change in the short run in all three countries. Fourth, the output elasticities of unskilled labor in the Japanese manufacturing sector are below unity in the short and intermediate run, but the manufacturing of the other two countries have experienced the overshootings of unskilled labor in the short and intermediate run. This finding may reflect the fact that Japanese unskilled labor includes much more human capital investment. As a result of that, Japanese firms hoard unskilled labor as well as skilled labor, although hoarding of unskilled labor is less than that of skilled labor. However, since Taiwanese and Korean unskilled labor not only have low level of skills which reflects low level of human capital investment, but also consist of low-productive labor, manufacturing firms over-adjust the skilled labor in response to fluctuating business cycles in order to compensate for the underadjustment of sluggish quasi-fixed factors.

Finally, elasticities calculated in the three factor model show rather unstable figures. For example, in the three factor model, short-run output elasticity of Japanese labor market is calculated rather high, 2.63, which does not properly reflect the Japanese labor market behavior, whereas the corresponding figure in the four factor model properly fit in the stable labor market condition of Japan. We conjecture this result comes from the fact that since labor, especially skilled labor, does not properly adjust to the output variation, it may be inappropriate to consider labor as a fully variable factor as in three factor model.

#### 4) Technical Change and Biases

We can also calculate the degree of technical change and biases of inputs due to technical change itself. We can define the absolute bias,  $b_i$ , and relative bias,  $b_{ij}$ , in the setting of several factors. Technical change ( $tp$ ) and two kinds of biases are defined as follows.

$$(22) \quad tp = -(\partial G / \partial t)(1/G)$$

$$(23) \quad b_i = (\partial i / \partial t)(1/i), \quad i = k, n, l, m$$

$$(24) \quad b_{ij} = \partial(i/j) \quad t, \quad i, j = k, n, l, m$$

Table 11 and 12 shows the technical change and absolute biases in three countries. We can find the following facts.

**Table 11**  
RATES AND ABSOLUTE BIASES OF TECHNICAL CHANGE IN THE  
THREE-FACTOR MODEL: SAMPLE AVERAGES

estimate	period	Japan	Taiwan	Korea
tp <sup>a)</sup>	1970s	-0.075	-2.342	-8.950
	1980s	1.431	-0.636	-2.840
	whole	0.528	-1.430	-5.690
b <sub>k</sub> <sup>b)</sup>	whole	0.016	0.033	-0.003
b <sub>l</sub>	whole	-0.003	0.005	0.018
b <sub>m</sub>	whole	-0.008	0.014	0.007

Notes: a)  $tp \equiv (\partial G / \partial t)(1/G) \times 100$ , where G is total variable cost and t is time.

b)  $b_i \equiv (\partial i / \partial t)(1/i)$ , where  $i = k, l$  and  $m$ .

**Table 12**  
RATES AND ABSOLUTE BIASES OF TECHNICAL CHANGE IN THE  
FOUR-FACTOR MODEL: AVERAGES OF SHORT-RUN EFFECTS  
OVER THE SAMPLE PERIODS

estimate	period	Japan	Taiwan	Korea
tp <sup>a)</sup>	1970s	-0.008	-0.159	-0.172
	1980s	0.024	0.029	-0.047
	whole	0.005	-0.059	-0.106
b <sub>k</sub> <sup>b)</sup>	whole	0.032	0.062	-0.014
b <sub>n</sub>	whole	0.021	0.005	0.019
b <sub>l</sub>	whole	0.037	0.019	0.057
b <sub>m</sub>	whole	-0.017	0.002	0.052

Notes: a)  $tp \equiv -(\partial G / \partial t)(1/G)$ , where G is total variable cost and t is time.

b)  $b_i \equiv (\partial i / \partial t)(1/i)$ , where  $i = k, n, l$  and  $m$ .

First, in both models, Japanese manufacturing has a positive technical change but other two countries have negative rates of technical change in the whole period. Compared with Taiwanese manufacturing, Korean manufacturing has recorded lower technical progress in the 1970s and 1980s. Second, three countries have higher rates of technical change in the 1970s than in the 1980s. Third, in both models capital-augmenting technical change has taken place in Japanese and Taiwanese manufacturing, but capital-diminishing technical change, in Korean manufacturing.

Fourth, skilled labor- and unskilled labor-augmenting technical changes have taken place in both models of Korea and Taiwan, while Japan's results are different in two kinds of models. Finally, in both model, materials-augmenting technical change has taken place in Korea and Taiwan, whereas materials-diminishing technical change, in Japan.

Table 13 and 14 show relative biases of factors due to technical change. First, the ratio of unskilled labor to skilled labor increased due to technical change in three countries in the 1970s and 1980s, whereas the ratio of unskilled labor to materials increased due to technical change in 1980s. Second, in Japan the ratio of capital to unskilled labor due to technical change increased slightly in the 1970s, but decreases in the 1980s. In Taiwan the ratio of skilled and unskilled labor to material caused by technical change decreased in the 1970s, but increased in the 1980s.

Third, the ratio of unskilled labor to materials increased due to technical change in 1980s. Fourth, in Japan the ratio of capital to unskilled labor due to technical change increased slightly in the 1970s, but decreases in the 1980s. In Taiwan the ratio of skilled and unskilled

**Table 13**  
RELATIVE BIASES OF TECHNICAL CHANGE IN THE  
THREE-FACTOR MODEL: SAMPLE AVERAGE

	Japan	Taiwan	Korea		Japan	Taiwan	Korea
$b_{kl}$	-7.11	5.20	-0.15	$b_{lm}$	0.18	8.39	2.74
$b_{km}$	-0.69	35.52	-0.41	$b_{mk}$	-0.58	0.22	-2.58
$b_{lk}$	-0.17	0.21	-8.72	$b_{ml}$	1.52	1.41	0.38

Note: a)  $b_{ij} \equiv [\partial(i/j)/\partial t] \times 100 = (b_i - b_j) \times 100$ , where  $i, j = k, l$  and  $m$ .

**Table 14**  
**RELATIVE BIASES OF TECHNICAL CHANGE IN THE**  
**FOUR-FACTOR MODEL: AVERAGES FOR THE SAMPLE PERIOD<sup>a)</sup>**

estimate	Japan	Taiwan	Korea		Japan	Taiwan	Korea
$b_{kn}$	1.1	5.7	-3.3	$b_{lk}$	0.5	-4.3	7.1
$b_{kl}$	-0.5	4.3	-7.1	$b_{ln}$	1.5	1.4	3.8
$b_{km}$	4.9	6.0	-6.6	$b_{lm}$	5.4	1.7	0.5
$b_{nk}$	-1.1	-5.7	3.4	$b_{mk}$	-4.9	-6.0	6.6
$b_{nl}$	-1.3	-1.4	-3.8	$b_{mn}$	-3.8	-0.3	3.3
$b_{nm}$	3.8	0.3	-3.3	$b_{ml}$	-5.4	-1.7	-0.5

Note: a)  $b_{ij} \equiv [\partial(i/j)/\partial t] \times 100 = (b_j - b_i) \times 100$ , where  $i, j = k, n, l$  and  $m$ .

labor to material caused by technical change decreased in the 1970s, but increased in the 1980s.

#### IV. Conclusion

In this paper, we try to analyze and to compare the production structures of Japanese and Taiwanese manufacturing industries with those of Korean manufacturing industry through the estimation of these three countries' dynamic interrelated factor demand functions. Through the interrelated aspect of the model, the effect of dynamic inter-market cross effect between nonproduction labor markets and capital markets could be analyzed. Also, we put emphasis on analyzing these three countries' factor market characteristics by measuring the output elasticity and own and cross price elasticities of two types of labor and the adjustment speed of quasi-fixed inputs to their long run equilibrium. In particular, we have measured the rates of technical changes of three countries' manufacturing sector as well as biases and trends of the technical change.

The empirical results of the models turn out to be reasonable and satisfy all the restrictions for the theoretical constraints concerned. The production structures of the Asian model shows not only certain common characteristics of factor market behavior but also some unique features that are inherent in each economy. Major findings of this paper are summarized as follows;



First, own-adjustment coefficient for capital market,  $m_{kk}$  is highest in Japan and Taiwan and Korea in order, whereas that of skilled labor  $m_{nn}$  is Taiwan, Korea and Japan in order. This means that the adjustment lag in Taiwanese and Korean capital market is fairly longer than that of Japanese capital market because of the high curb market interest rate and high search cost of capital in distorted dual structure of Taiwanese and Korean capital market.

Second, capital and skilled labor turn out to be dynamic complements in all three countries. Furthermore, the cross-adjustment coefficients for the Taiwan and Korea are much higher than those of Japan, which implies that the dynamic intermarket spillover effects in NICs of Taiwan and Korea are stronger than those of Japan, as is expected.

Third, in the short-run, distinct hoarding phenomena have been observed for all three countries' skilled labor market as well as capital market. On the other hand, there exist overshooting in all three countries' material markets for output variation. In four factor model, only the Korean unskilled labor market shows high output elasticities in the short-run and even in the intermediate-run, which implies that in Korea the unskilled labor market absorbed substantial burdens of factor market adjustment from output fluctuations.

Fourth, for the own- and cross-price elasticities among factors, we observed a significant diversity among three countries. However, the capital and skilled labor are complementary factors, whereas materials and skilled labor are substitutes in all three countries. The own- and cross-price elasticities of our model are lower than those of other studies using static models, such as Choi (1987) and Saito and Tokutsu (1991), which may come from the dynamic properties of our model.

Fifth, the elasticities calculated in the three factor model show rather unstable figures. For example, in the three factor model, short-run output elasticity of Japanese labor market is calculated quite high, which does not properly reflect the Japanese labor market behavior, whereas the corresponding figures in the four factor model properly fits in the stable labor market condition of Japan. We conjecture this result comes from the fact that since labor, especially skilled labor, does not properly adjust to the output variation, it may be inappropriate to consider labor as a fully variable factor as in three factor model.

Finally, in both models, Japanese manufacturing has a positive technical change but other two countries have negative rates of tech-

nical change in the whole period. Compared with Taiwanese manufacturing, Korean manufacturing has recorded lower technical progress in the 1970s and 1980s. In both model capital-augmenting technical change has taken place in Japanese and Taiwanese manufacturing, but capital-diminishing technical change, in Korean manufacturing. Japanese manufacturing sector has materials-saving technology, Taiwanese manufacturing sector has capital-using technology, and Korean manufacturing sector has capital-saving and unskilled labor-using technology in terms of any of the other factors.

This research can be extended in several directions. In terms of model specification, we can endonize pricing in the output market and input market under the assumption of imperfect competition in the output market as well as input market. This might be important since degree of imperfect competition in those three countries is not insignificant. Adopting non-static factor price expectation would also give an interesting result. In order to dig in more detail implications of this kind of study, it is also necessary to extend the analysis into that of sub-industry level.

## Appendix

### Data Sources and Construction

The model requires various data for the total manufacturing sector in Korea, Taiwan and Japan. The data range from 1973 to 1987 for Korea and Taiwan, and from 1971 to 1985 for Japan. The data used in this model have been constructed as follows.

#### *1. Gross Output*

All values of gross output in three countries are transformed into those in terms of the 1980's constant price. For Korea, the data of gross output are obtained from 'Survey of Manufacturing and Mining Statistics,' published annually by Korean Economic Planning Board. For Japan, those data are obtained from 'Yearbook of National Statistics,' published annually by Economic Planning Board. For Taiwan, those data are obtained from 'National Income of Republic of China,' published by Directorate-General of Budget, Accounting and Statistics. The GNP deflator is used to calculated real gross output from nominal gross output.

## *2. Materials*

The figures of materials data in three countries are also obtained from the same sources as gross output data. Wholesale price index is used as the price of materials.

## *3. Labor*

There are two kinds of labor used in this model; skilled labor and unskilled labor. Skilled labor is measured as the existing stock of skilled labor, and unskilled labor is measured in terms of men-hours worked. Men-hours worked by unskilled labor are calculated as the number of unskilled workers times 12 hours worked per month. For the price of skilled labor, we use the annual compensations that one skilled worker earns a year. For the price of unskilled labor, hourly wage rate is used. The data sources are 'Monthly Statistics of Labor,' published by Ministry of Labor for Korea, 'Survey Report on Monthly Statistics,' published by Ministry of Labor for Japan, and 'National Income of Republic of China,' published by Section of Main Statistics, Executive Yuan for Taiwan.

## *4. Capital*

Net capital stocks used in this model are measured in terms of the 1980's appropriate capital price, that is, transformed into real net capital stocks. The figures of Korean net capital stocks are obtained from Pyo's working paper published by Korea Development Institute. For Japan and Taiwan, the figures of net capital stocks are obtained in the same sources as the gross output.

To calculate the user cost of capital, capital price, depreciation rate, real interest rate and tax rate of manufacturing sectors are required. For capital price, we used the investment deflator from the national accounting of each country. Depreciation rate is set to 0.15 for Korea and Taiwan, and 0.10 for Japan. The tax rate is calculated as the ratio of corporate income tax amount to the total variable cost plus the adjustment cost of quasi-fixed factors. We assume that the ratio of corporate income tax amount to value added of manufacturing sector is approximately equal to the ratio of national tax amount to gross national products. Then we calculate the tax amount and tax rate in the manufacturing sectors. Yield of corporate bond, yield of government bond and discount rate of commercial loans are used respectively as interest rate of Korea, Japan and Taiwan. To calculate the real interest

rate, we subtract percentage change rate of investment deflators from the above-mentioned nominal interest rates of each country.

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