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동학모형에서 기술변화와 편향성 : 한국, 일본, 그리고 대만 제조업의 비교연구

나 호 수*

Technical Change and Bias in a Dynamic model : the Comparison of the Manufacturing Industries of Korea, Japan and Taiwan

*Ho-Soo Nah**

요 약

최근 한국, 일본 그리고 대만의 제조업 생산품은 세계시장에서 전보다 심한 경쟁을 경험하고 있고, 각국은 자국생산물의 가격경쟁력을 확보하기 위해 노력하고 있다. 이러한 시점에서 3국의 제조업생산기술의 구조를 파악하고자 하는 것이 본 논문의 목적이다. 특히 이 3국은 지난 수십년 동안 급속한 경제성장을 이룩해 왔고 정부주도에 의한 경제개발이라는 점에서, 또한 서로 인접된 국가라는 점에서 흥미의 대상이 된다 하겠다. 이러한 국가들의 급속한 경제성장의 여러가지 요인들 중에서 기술변화가 중요한 부분을 차지할 것으로 예상된다. 따라서 본 논문에서는 최근에 개발된 동학모형에서 이 삼국의 기술변화율과 생산요소에 대한 기술의 편향성을 측정하고자 한다. 이 모형은 기존의 모형과는 다르게 생산요소가 상호간의 의존적인 관계에서 장기적인 목표에 수렴해간다는 상호의존적 동학모형이고 조정의 비용을 고려하면서 장기에서 해(solution)를 구할 뿐만아니라 계량경제학적인 측면에서 파라메터의 추정이 가능하게 변형할 수 있다는 점에서 매우 유용한 모형이다. 이 모형을 한국, 일본 그리고 대만의 자료에 적용하여 측정한 결과에 의하면 일본이 기술증가속도가 가장 빠르고 한국이 가장 낮게 나타났고 삼국 모두 70년대에 비하여 80년대에 개선되고 있다. 또한 삼국 모두에서 기술변화가 노동을 많이 사용하는 방향으로 야기되어 왔고, 상대적 편향성을 살펴보면 일본은 원자재 절약적 기술변화, 대만은 자본사용적 기술변화, 그리고 한국은 자본절약적, 비숙련직노동 사용적 기술변화가 야기되어 왔음을 알 수 있다. 그리

* Department of International Trade, College of Social Sciences, Korea Maritime University, Pusan, Korea.

고 70년대에 비하여 80년대에는 기술변화로 인하여 숙련직노동에 비해 비숙련직노동의 비율이 증가되고, 또한 원자재에 비해 비숙련직 노동의 비율이 증가되어 왔다는 것을 측정결과는 보여주고 있다. 그런데 대만의 경우에는 기술변화로 인하여 원자재에 비교하여 숙련직, 비숙련직 노동의 비율은 70년대에 감소되다가 80년대에 증가하는 것으로 측정되었다.

I. Introduction

Since Christensen, Jorgenson and Lau(1971, 1973) introduced the translog functions to the analyses of production structure, many studies in this field can measure the rates and biases of technical change more accurately in the sense that these models permit us to calculate distinct rates and biases of technical progress each year. This translog function can be envisaged as a second-order Taylor's series approximation in logarithms to an arbitrary function. This function is general in that it can measure various own and cross elasticities of factors, and also can derive some additional informations from itself based on economic theory. But this function has some difficulties in analysing the optimal transition path of factors from the short-run to the long-run. Recently using this kind of quadratic functional form, some studies have tried to build models which distinguishe fixed and variable factors, and then derive the short-run and long-run effects of factors. These studies belong to Morrison and Berndt(1981), Pindyck and Rotemberg(1983) and Nadiri and Prucha(1985). In particular, Nadiri and Prucha's model has some advantages in that it can measure explcitly the cross adjustment of factors and permit some conveniences of parameter estimation. We adopt this approach in analysing the production structure of manufacturing industries of Korea, Japan and Taiwan.

These Asian countries have experienced phenomenal economic growth for some decades.[1] The engine of these countries' economic growth seems to be related to the technical progress of manufacturing industries. So we are interested in observing some characteristics of technical change for these industries of three countries. Section II explains the process of the derivation and econometric formulation of our model. Section III presents the empirical results and section IV summarizes and concludes our paper.

II. The Model

Our model is formulated by specifying the system of the factor demand equations in the discrete forms. This discrete formulation may be more plausible than the continuous formulation because

1) For the explanatoin of factors of these three countries' economic growth, see Kuznetz(1988).

of the discreteness of the economic data. Traditionally, most papers which deal with dynamic factor demand models build their models in the continuous time, consequently obtain their solutions specified in the form of differential equations, and then use a discrete linear approximation for empirical analyses.[2] These models have an important shortcoming in that they should assume the separability of quasi-fixed factors for empirical applications.[3] Recently discrete approaches have shown that discrete formulations can permit the non-separability of quasi-fixed factors. The idea that separability assumption can be relaxed was initiated by Epstein and Yatchew (1985) and Prucha and Nadiri (1986).

We adopt this idea to estimate the parameter of the dynamic interrelated factor demand models in non-separable forms. We assume static expectations on exogenous variables.[4] We also assume the total manufacturing secter of a country behaves like a typical competitive firm, pursuing profit maximization. This firm uses two variable factors and two quasi-fixed factors in producing a single output and pays the adjustment cost of quasi-fixed factors.

We assume that the firm's technology is described as the following general production.

$$y_t = F(v_t,\ x_{t-2},\ \Delta x_t\ ;\ T_t) \qquad (1)$$

, where y_t is output, $v_t = [v_{1t}\ v_{2t}]'$ is the vector of variable fectors, and $x_t = [x_{1t}\ x_{2t}]'$ is the vector of stocks of the quasi-fixed factors 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 assumd to change uniformly in the process of time path, that is, $T_t = t$.

The firm's factor markets are assumed to be perfectly competitive. In this case we can describe production technology in terms of the normalized restricted cost function defined as $G(w_t,\ x_{t-1},\ \Delta x_t,\ y_t\ ;\ t) = \hat{v}_{1t} + w_t \hat{v}_{2t}$, where $\hat{v}_{1t}$ and $\hat{v}_{2t}$ denote the cost-minimizing variable factors and w_t denotes the price of the second variable input v_{1t} normalized by that of the first variable input v_{2t}.

According to Lau (1976), the function G(·) has the following properties :

1) G(·) is decreasing in x_t and Δx_t and increasing in w_t and y_t : $\partial G/\partial x_i < 0$, $\partial G/\partial \Delta x_i < 0$, $\partial G/\partial w_t > 0$, $\partial G/\partial y > 0$, $_{i=1,2}$.

2) For the process of linear appoximation in these dynamic factor demand model, see Treadway (1969, 1971, 1974) and Mortenson (1973).

3) These types of papers are Denny, Fuss and Wavermann (1981), Morrison and Berndt (1981), Berndt, Morrison and Watkins (1981).

4) 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 numbers of parameter estimates. In particular, this study is dealing with developing economies and has faced a serious degree of freedom because of data constraint, so we adopt the assumption of static expectation.

2) G(·) is concave in w_t.

3) G(·) is convex in x_t and Δx_t.

4) $\partial G(\cdot)/\partial w_t = v_{2t}$, the cost-minimizing factor level.[5)]

In our empirical analysis 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 factors.[6)] w_t is then the real wage rate of skilled labor normalized by materials price.

The functional form of G(·) in our model is assumed to take the following form which has constant returns to scale technology.[7)]

$$
\begin{aligned}
G(w_t,\ x_{t-1},\ \Delta x_t,\ y_t,\ t) &= G(w_t,\ x_{t-1}/y_t,\ \Delta x_t/y_t,\ t) \\
&= y_t[a_o + a_w w_t + a_{ww} w_t^2/2 + a_{tw} w_t t + a_t t] + a_k k_{t-1} + a_n n_{t-1} + a_{kk}(k_{t-1}^2/y_t)/2 \\
&\quad + a_{nn}(n_{t-1}^2/y_t)/2 + a_{kn} k_{t-1} n_{t-1}/y_t + \dot{a}_k \Delta k_t + \dot{a}_n \Delta n_t + g_{kk}(\Delta k_t^2/y_t)/2 \\
&\quad + g_{nn}(\Delta n_t^2/y_t)/2 + g_{kn}(\Delta k_t \Delta n_t)/y_t + a_{wk} w_t k_{t-1} + a_{wn} w_t n_{t-1} + \dot{a}_{wk} w_t \Delta k_t \\
&\quad + \dot{a}_{wn} w_t \Delta n_t + \dot{a}_{kk} k_{t-1} \Delta k_t + \dot{a}_{nn} n_{t-1} \Delta n_t + \dot{a}_{kn} k_{t-1} \Delta n_t + \dot{a}_{nk} n_{t-1} \Delta k_t + a_{tk} k_{t-1} t \\
&\quad + a_{tn} n_{t-1} t + \dot{a}_{tk} \Delta k_t t + \dot{a}_{tn} \Delta n_t t
\end{aligned} \tag{2}
$$

Form the total variable cost function G(·), we can separate the internal cost of adjustment as follows.

$$
\begin{aligned}
G(\Delta k_t,\ \Delta n_t) &= \dot{a}_k \Delta k_t + \dot{a}_n \Delta n_t + g_{kk}(\Delta k_t^2/y_t)/2 + g_{nn}(\Delta n_t^2/y_t)/2 \\
&\quad + g_{kn}(\Delta k_t \Delta n_t)/y_t + \dot{a}_{wk} w_t \Delta k + \dot{a}_{wn} w_t \Delta n_t + \dot{a}_{kk} k_{t-1} \Delta k_t \\
&\quad + \dot{a}_{nn} n_{t-1} \Delta n_t + \dot{a}_{kn} k_{t-1} \Delta n_t + \dot{a}_{nk} n_{t-1} \Delta k_t + \dot{a}_{tk} \Delta k_t t + \dot{a}_{tn} \Delta n_t t
\end{aligned} \tag{3}
$$

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

$$
\begin{aligned}
\partial G/\partial \Delta k_t = \partial C/\partial \Delta k_t &= \dot{a}_k + g_{kk} \Delta k_t/y_t + g_{kn} \Delta n_t/y_t + \dot{a}_{wk} w_k + \dot{a}_{kk} k_{t-1} \\
&\quad + \dot{a}_{nk} n_{t-1} + \dot{a}_{tk} t = 0
\end{aligned} \tag{4-1}
$$

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5) This relation is called Shephard's lemma.

6) In our 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 worked. This is because we intend to follow the assumption that skilled labor is fixed and unskilled labor is variable in the short run.

7) This functional form has a quadratic form in all arguments except time variable, t. We assume that the coefficient of t^2 equals zero.

$$\partial G/\partial \Delta n_t = \partial C/\partial \Delta n_t = \dot{\alpha}_n + g_{nn}\Delta n_t/y_t + g_{kn}\Delta k_t/y_t + \dot{\alpha}_{wn}w_t + \dot{\alpha}_{nn}n_{t-1} + \dot{\alpha}_{kn}k_{t-1} + \dot{\alpha}_{tn}t = 0 \quad (4\text{-}2)$$

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

$$\dot{\alpha}_k = \dot{\alpha}_n = \dot{\alpha}_{wk} = \dot{\alpha}_{wn} = \dot{\alpha}_{kk} = \dot{\alpha}_{nn} = \dot{\alpha}_{nk} = \dot{\alpha}_{kn} = \dot{\alpha}_{tk} = \dot{\alpha}_{tn} = 0 \quad (5)$$

We also assume $g_{kn}=0$, which implies separability in adjustment costs of quasi-fixed factors. In our model we do not impose the restriction $a_{kn}=0$, and therefore we assume non-separability of quasi-fixed factors.[8] We denote the real discount rate, the corporate tax rate, the depreciation rate of capital and the depreciation rate of unskilled labor as r_t, u_t, δ_k and δ_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 expectations of exogenous variables, the firm's optimization problem at period t can be stated as follows.

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

, where $G(t+s)=G(w_t, k_{t+s}, n_{t+s}, \Delta k_{t+s}, \Delta n_{t+s}, y_t, t+s)$,[9] and q_{kt} and q_{nt} are 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 equations is necessary conditions to solve this dynamic programming problem.

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

, where $B=\begin{pmatrix} g_{kk} & 0 \\ 0 & g_{nn} \end{pmatrix}$, $A=\begin{pmatrix} a_{kk} & a_{kn} \\ a_{kn} & a_{nn} \end{pmatrix}$

and $a_t = -\begin{pmatrix} a_k + a_w w_t + a_{tk}t + c_{kt} \\ a_n + a_{wn}w_t + a_{tn}t + c_{nt} \end{pmatrix}$

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

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

8) This separability assumption is being employed in the models specified in continuous forms for empirical applications because in the process of solving this dynamic programming problem they cannot lead to the explicit equations of endogenous variables to estimate the parameters of the models.

9) Under static expectetions, the current values of exogenous variables are equal to future values of them.

as follows.

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

, where $x_t^* = [k_t^* \; n_t^*]'$ is the steady state solution of (6).

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

$$BM^2 + (A + r_t B)M - A = 0 \tag{9}$$

We define the matrix C as follows.

$$C = -BM = \begin{pmatrix} c_{kk} & c_{kn} \\ c_{kn} & c_{nn} \end{pmatrix} \tag{10}$$

Then we can express A and D in terms of B and C.[10]

$$A = C - (1+r)[B - B(C+B)^{-1}B] \tag{11}$$

$$D = B^{-1} + (1+r)(C - rB)^{-1} = \begin{pmatrix} d_{kk} & d_{kn} \\ d_{kn} & d_{nn} \end{pmatrix} \tag{12}$$

Substituting (11) and (12) into (9) we can write the demand equations for the quasi-fixed factors in the following forms.

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

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

We can derive the demand equations for two variable factors from the normalized restricted cost function using Shephard's lemma, $l_t = \partial G(t)/\partial w_t$, $m_t = G(t) - w_t l_t$.

$$l_t = (a_w + a_{ww}w_t + a_{tw}t)y_t + a_{wk}k_{t-1} + a_{wn}n_{t-1} \tag{15}$$

$$m_t = (a_0 + a_{ww}w_t^2 + a_t t)y_t + a_k k_{t-1} + a_n n_{t-1} + a_{nn}n_{t-1}^2/(2y_t)$$
$$+ a_{kk}k_{t-1}^2/(2y_t) + a_{kn}k_{t-1}n_{t-1}/y_t + g_{kk}\Delta k_k^2/(2y_t)$$

10) For the derivation of these expressions (11) and (12), we have to use the idea of Prucha and Nadir(1986), (I–M) $[I-r(I-M)]^{-1}B^{-1} = -(1/r)\ \{B^{-1} + (1/r)[C-(1-r)/B^{-1}\}$. 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).

$$+g_{nn}\Delta n_t^2/(2y_t)+a_{tk}k_{t-1}t+a_{tn}k_{t-1}t \qquad (16)$$

The four equations we have to estimate consist of two equations (13) and (14), and two modified equations of (15) and (16), where a_{kk}, a_{nn}, a_{kn}, d_{kk}, d_{nn}, and d_{kn} are replaced by c_{kk}, c_{kk}, c_{nn}, g_{kk}, and g_{nn}.

III. Empirical Results

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

1. 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 transformed from current values of them into real variables using the respective appropriate deflators. Uuskilled labor is measured in terms of men-hours worked a year and siklled 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.

2. 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.[11]

11) There are three kinds of FIML numerical methods in TSP of version 4.0. It turns out that Davidson–Fletcher–Powell method is much slower than the other methods, Gauss method and Grad method, but provides stable converging parameter estimates at any initial values of parameters.

Table 1. Full information maxium likelihood parameter estimates of the dynamic interrelated factor demand model for the total manufacturing sectors of Japan for 1971–1985, and Taiwan and Korea for 1973–1987[a)]

parameter	Japan		Taiwan		Korea	
a_o	1.087 (4.832)		4.629 (4.009)		1.398 (7.881)	
a_k	−3.470 (−2.135)		3.396 (1.979)		−1.556 (−3.183)	
a_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 (1.667)		11.698 (1.491)		8.393 (3.650)	
g_{nn}	18.345 (1.437)		11.846 (1.396)		4.339 (4.017)	
a_w	0.078 (2.127)		1.165 (3.168)		1.051 (13.139)	
a_{ww}	−0.056 (−1.965)		−0.159 (−1.705)		−0.027 (−1.063)	
a_{wk}	−0.166 (−4.740)		−1.345 (−4.156)		−0.741 (−8.470)	
a_{wn}	0.501 (7.428)		1.805 (4.007)		−0.372 (−4.852)	
a_t	0.145 (3.126)		0.102 (0.781)		0.021 (0.980)	
a_{tw}	0.005 (3.487)		0.030 (1.198)		0.032 (4.769)	
a_{tk}	−0.297 (−3.180)		−0.419 (−4.192)		0.086 (3.126)	
a_{tn}	−0.008 (−0.380)		0.226 (1.499)		−0.098 (−4.776)	
log of LF[b)]	168.094		120.199		145.581	
	R^2	D-W	R^2	D-W	R^2	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

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.

The parameter estimates of our model are presented in table 1. The fittings of the model are quite good in each country in that the values of R^2's are all greater than 0.96. T–values of estimated coefficients in Japanese and Korean manufacturing sectors are mostly statistically significant, but Taiwanese model have relatively more insignificant coefficients than the other countries. Dubin–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(·) in x_t and Δx_t, and concavity in w_t imply the following inequality parameter constraints.

$$a_{kk} > 0,\quad a_{nn} > 0,\quad a_{kk}a_{nn} - a_{kn}^2 > 0$$

$$g_{kk} > 0,\quad g_{nn} > 0,\quad a_{ww} < 0$$

Table 2 shows a_{kk}, a_{kn}, and a_{nn} derived from parameter estimates in Table 1. All restrictions of three countries are satisfied.

Table 2. The other parameter estimates calculated from the FIML parameter estimates of the dynamic interrelated factor demand model for the manufacturing sectors of Japan, Taiwan and Korea[a)]

parameter	Japan	Taiwan	Korea
a_{kk}	9.462 (0.762)	5.213 (0.560)	2.257 (0.121)
a_{kn}	−1.949 (0.125)	−5.873 (0.410)	−2.228 (0.077)
a_{nn}	3.288 (0.406)	15.514 (1.282)	4.244 (0.169)

a) The sample standard deviations are given in parentheses.

3. Technical change and bias

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

Table 3. Retes and absolute biases of technical change in the total manufacturing sectors of Japan, Taiwan and Korea : averages of short-run effects over the sample periods

estimate	period	Japan	Taiwan	Korea
tp[a)]	1970s	−0.008	−0.159	−0.172
	1980s	0.024	0.029	−0.047
	total	0.005	−0.059	−0.106
b_k[b)]	1970s	0.035	0.077	−0.015
	1980s	0.027	0.050	−0.012
	total	0.032	0.062	−0.014
b_n	1970s	0.018	0.005	0.024
	1980s	0.024	0.005	0.015
	total	0.021	0.019	0.057
b_l	1970s	0.029	0.014	0.063
	1980s	0.049	0.023	0.052
	total	0.037	0.019	0.057
b_m	1970s	−0.001	0.058	0.060
	1980s	−0.042	−0.048	0.046
	total	−0.017	0.002	0.052

a) $tp=(\partial G/\partial t)(1/G)$ where G is total variable cost and t is time.
b) $b_i=(\partial i/\partial t)(1/i)$ where i=k,n,l and m.

$$tp=(\partial G/\partial t)(1/G) \quad (21)$$

$$b_i=(\partial i/\partial t)(1/t),\ {}_{i=k,n,l,m} \quad (22)$$

$$b_{ij}=\partial(i/j)/\partial t,\ {}_{i,j=k,n,l,m} \quad (23)$$

Table 3 shows the technical change and absolute biases in three countries. We can find the following facts.

First, Japanese manufacturing has a positive technical change but the other two countries have negative rates of technical change in the whole period. Compared with Taiwanese manufacturing, Korean manufacturing has recorded the lower technical progress in the 1970s and 1980s.

Second, three countries have higher rates of technical change in the 1980s than in the 1970s, which means that these countries has improved the adapability to the oil shock in the 1980s in comparison with the 1970s.

Third, skilled labor-and unskilled labor-augmenting technical changes have taken place in three countries.

Fourth, capital–augmenting technical change has taken place in Japanese and Taiwanese manufacturing, but capital–diminishing technical change, in Korean manufacturing.

Fifth, materials–augmenting technical change have taken place in Korea, but materials–diminishing technical change, in Japan.

Sixth, in Taiwan materials–diminishing technical change of the 1970s has changed to the augmenting direction in the 1980s.

Table 4 shows relative biases of inputs due to technical change. Some points of interest are presented as follows.

Table 4. Relative biases of technical change in the total manufacturing sectors of Japan, Taiwan and Korea : averages for the sample periods[3)]

estimate	Japan			Taiwan			Korea		
	70s	80s	total	70s	80s	total	70s	80s	total
b_{kn}	1.7	0.3	1.1	7.2	4.5	5.7	−3.6	−2.7	−3.3
b_{kl}	0.6	−2.2	−0.5	6.3	2.7	4.3	−7.8	−6.4	−7.1
b_{km}	3.6	7.4	4.9	1.9	9.8	6.0	−7.5	−5.8	−6.6
b_{nk}	−1.7	−0.3	−1.1	−7.2	−4.5	−5.7	3.6	2.7	3.4
b_{nl}	−1.1	−2.5	−1.3	−0.9	−1.8	−1.4	−3.9	−3.7	−3.8
b_{nm}	1.9	6.6	3.8	−5.3	4.3	0.3	−3.6	−3.1	−3.3
b_{lk}	−0.6	2.2	0.5	−6.3	−2.7	−4.3	7.8	6.4	7.1
b_{ln}	1.1	2.5	1.5	0.9	1.8	1.4	3.9	3.7	3.8
b_{lm}	3.0	9.1	5.4	−4.4	2.5	1.7	0.3	0.6	0.5
b_{mk}	−3.6	−6.9	−4.9	−1.9	−9.8	−6.0	7.5	5.8	6.6
b_{mn}	−1.9	−6.6	−3.8	5.3	−4.3	−0.3	3.6	3.1	3.3
b_{ml}	−3.0	−9.1	−5.4	4.4	−2.5	−1.7	−0.3	−0.6	−0.5

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

First, 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.

Second, the ratio of unskilled labor to skilled labor increased due to technical change in three countries in the 1970s and 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 labor to material caused by technical change decreased in the 1970s, but increased in the 1980s.

IV. Concluding remarks

We attempted to derive a dynamic optimization, applied it to the manufacturing sectors of Korea, Japan and Taiwan and measured the rates and biases of technical change for each country. Major findings are summarized as follows.

First, all parameter estimates of our study have the same signs as expected from the neoclassical theory of firm and most estimated coefficients are statistically significant. The fittness of our model is quite good.

Second, while Korean manufacturing has experienced the lowest rate of technical progress, Japanese manufacturing has recorded positive and fastest technical change.

Third, three countries have experienced higher rates of technical progress in the 1980s than in the 1970s.

Fourth, skilled labor and unskilled labor augmenting technical changes have taken place in three countries for the whole period.

Fourth, Korean manufacturing has capital-saving technology, but Taiwanese manufacturing has capital-using technology.

Fifth, The ratio of unskilled labor to skilled labor due to technical change has been higher in three countries.

This study has many things to be desired for further researches.

Above all, the length of our data series needs to be longer and more appropriate data should be available. Also continuous formulation of our model is a good way to find some characteristics of these economies. But this work may be possible but very difficult in the transformation of derived theoretical model into the manageable econometric equations.

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