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An International Comparison of the Input-Output Structure: Europe, the U.S.A., and East Asia

By
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Abstract

Multi-sectoral production functions are estimated for six countries based on input-output tables of the Leontief type. The adopted functional form is of the 2-level CES type, which well serves for avoiding possible multicolliniarity in the econometric estimation. The result satisfies the quasi-concavity conditions of the production function for all countries and industries. The obtained estimates of the price elasticity of factor demand and the elasticity of substitution among various intermediate inputs are thus reasonable both in sign and magnitude. Variation in parameters across industries and countries suggests that the estimates can serve as references for the proper calibration of parameters in the computable general equilibrium model.

1. Introduction

Most studies on input-output analysis are based on the assumption of the constancy of input coefficients. Mainly for its simplicity and empirical utility, the assumption of fixed input coefficients has been widely accepted by scholars and applied to several fields of interest in inter-industry studies. From the viewpoint of the neoclassical theory of firm, however, input coefficients can be regarded as the function of prices with a given level of technology. In this sense it may by more realistic to assume that input coefficients vary in response to a price change even in the short-run with a given technology level.

The computable general equilibrium (CGE) model, which has been extensively applied to the empirical analysis of inter-industry studies in recent years, is also grounded in this neoclassical framework. It should be noted, however, that in most cases the parameters in the CGE model are obtained by calibration without statistical examination. One of the most difficult problems of estimating the endogenized input

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coefficients in the neoclassical framework may lie in multicollinearity due to the large number of parameters to be estimated compared to the relatively scarce sample observations.

The main purpose of this study is to endogenize the input coefficients by the full use of the bench-mark input-output tables, and the time series data of capital, labor and aggregated intermediate materials. The essential feature of our method is that it is designed so as to avoid the multicollinearity problem by assuming a two-level CES function of the KLEM type[1] and weak separability of the input structure. The model is estimated for six countries in Europe, the U.S.A., and East Asia. The estimated results of all countries are compared, a comparison which serves not only to show particular features of the production structure of each country, but also to examine the empirical validity of our approach as extensively as possible.

The rest of the paper is organized as follows. The model and its estimation method are explained in Section 2. Sections 3 and 4 are devoted to the interpretation of the empirical results for the aggregated level (KLEM) and individual n industry level, respectively. The estimated result at the aggregated level facilitates a comparison of our estimates with those others, and helps us derive practical implications from our empirical study. The estimated result at the individual industry level amount show the final form of our model. It may serve for the construction of an input-output model of more than 20 sectors with endogenous input coefficients. Finally, Section 5 is devoted to concluding remarks and the economic implications of the study.

2. The Model

The basic accounting framework of our model is an input-output table of the Leontief type. In this framework all intermediate inputs from industries should be treated as factors of production, as well as labor and capital inputs. This is very likely to cause multicollinearity in an estimation based on time series data, due to the large number of explanatory variables compared to the number of samples.

One effective way to eliminate this problem may be to aggregate several inputs into the aggregate input with the proper aggregator and to decompose the estimation procedure into a series of stages in order to decrease the number of parameters to be estimated at each stage. Under the assumption of a perfect market and the cost minimizing principle of firms' behavior, it is well known that if the price for the aggregate variable is defined properly by the dual function to the aggregator, the optimization in each aggregation level is exactly equivalent to global optimization. Based on this idea, we aggregate the intermediate inputs of industry X_{ji} ($j = 1,\ldots,n$) into energy materials E_i and non-energy materials M_i and then adopt the 2-level CES production function developed by Sato (1967).[2]

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[1] KLEM stands for four factors of production, K(capital), L(labor), E(energy), and M(material), respectively.

[2] Nemoto(1984) also estimated the 2-level CES production function of the KLEM type for three energy-intensive industries based on cross section data in Japan.

Table 1 presents the basic accounting scheme for our multi-sectoral production function. First of all, let us explain the aggregation method of intermediate inputs X_{ji}'s into aggregated non-energy materials M_i and aggregated energy materials E_i at the individual industry level. Equations (1) and (2) show that M_i and E_i are related to intermediate inputs X_{ji}'s by the Cobb-Douglas function with constant return to scale.

$$M_i = m_i \prod_{j\in j_m} X_{ji}^{b_{ji}}, \quad \sum_{j\in j_m} b_{ji} = 1, \tag{1}$$

$$E_i = e_i \prod_{j\in j_e} X_{ji}^{c_{ji}}, \quad \sum_{j\in je} c_{ji} = 1. \tag{2}$$

Under the assumption of constant return to scale, b_{ji}'s and c_{ji}'s can be estimated as the relative shares of VX_{ji}'s in VM_i and VE_i respectively. That is to say,

$$b_{ji} = a_{ji} \Big/ \sum_{j\in j_m} a_{ji}, \tag{3}$$

$$c_{ji} = a_{ji} \Big/ \sum_{j\in je} a_{ji}, \tag{4}$$

where a_{ji}'s are input coefficients in value terms.

In the actual estimation, three industries, "coal and oil mining", "coal and oil products" and "electricity and gas" in the input-output tables are defined as the energy supplying industries. The aggregate prices of PM_i and PE_i are defined as the dual function to the Cobb-Douglas aggregators (1) and (2),

$$PM_i = (m_i \prod_{j\in j_m} b_{ji}^{b_{ji}})^{-1} \prod_{j\in j_m} PX_j^{b_{ji}}, \tag{5}$$

$$PE_i = (e_i \prod_{j\in j_e} c_{ji}^{c_{ji}})^{-1} \prod_{j\in j_e} PX_j^{c_{ji}}. \tag{6}$$

Scale parameters of the production function, m_i and e_i, can be obtained by setting them to unity in the base year. In the calculation of PM_i and PE_i above, we assume that the exponent parameters, b_{ji} and c_{ji}, vary over time, reflecting the change of technology but these changes are just compensated for by the accompanying change in m_i and e_i respectively.[3] As is seen in equations (1) and (2), this implies that the change in b_{ji} and c_{ji} over time leads to neither an increase nor a decrease in total factor productivity in the production of M_i and E_i. Using these aggregate prices, real non-energy input and energy input at constant price are estimated as VM_i/PM_i and VE_i/PE_i, respectively.

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[3] In other words, the estimates for the rate of change in m_i and e_i are represented as

$$\Delta m_i / m_{i,-1} = \sum_{j\in j_m} -\Delta b_{ji} \ln X_{ji,} \text{ , and } \Delta e_i / e_{i,-1} = \sum_{j\in j_e} -\Delta c_{ji} \ln X_{ji,} \,.$$

Table 1: Basic Accounting Scheme

	Quantity				Value				Price			
(a)	The individual industry level											
Industry	(1)	(2)	...	(n)	(1)	(2)	...	(n)	(1)	(2)	...	(n)
Inputs	X_{11}	X_{12}	...	X_{1n}	VX_{11}	VX_{12}	...	VX_{1n}	PX_1	PX_1	...	PX_1
	X_{21}	X_{22}	...	X_{2n}	VX_{21}	VX_{22}	...	VX_{2n}	PX_2	PX_2	...	PX_2
	.	.		.	.	.		.	.	.		.
	X_{n1}	X_{n2}	...	X_{nn}	VX_{n1}	VX_{n2}	...	VX_{nn}	PX_n	PX_n	...	PX_n
	K_1	K_2	...	K_n	VK_1	VK_2	...	VK_n	PK_1	PK_2	...	PK_n
	L_1	L_2	...	L_n	VL_1	VL_2	...	VL_n	W_1	W_2	...	W_n
Output	X_1	X_2	...	X_n	VX_1	VX_2	...	VX_n	PX_1	PX_2	...	PX_n
(b)	The first aggregated industry level											
Inputs	M_1	M_2	...	M_n	VM_1	VM_2	...	VM_n	PM_1	PM_2	...	PM_n
	E_1	E_2	...	E_n	VE_1	VE_2	...	VE_n	PE_1	PE_2	...	PE_n
	K_1	K_2	...	K_n	VK_1	VK_2	...	VK_n	PK_1	PK_2	...	PK_n
	L_1	L_2	...	L_n	VL_1	VL_2	...	VL_n	W_1	W_2	...	W_n
Output	X_1	X_2	...	X_n	VX_1	VX_2	...	VX_n	PX_1	PX_2	...	PX_n
(c)	The second aggregated industry level*											
Inputs	M_1	M_2	...	M_n	VM_1	VM_2	...	VM_n	PM_1	PM_2	...	PM_n
	EK_1	EK_2	...	EK_n	VEK_1	VEK_2	...	VEK_n	PEK_1	PEK_2	...	PEK_n
	L_1	L_2	...	L_n	VL_1	VL_2	...	VL_n	W_1	W_2	...	W_n
Output	X_1	X_2	...	X_n	VX_1	VX_2	...	VX_n	PX_1	PX_2	...	PX_n

* Weak separability of energy and capital is assumed.
The definition of the symbols is provided in Appendix A.

At the first aggregation level, the energy-capital aggregate input EK_i is constructed by the CES aggregation function, if energy E_i, and capital K_i are weak-separable from other inputs, M_i and L_i. The aggregator at this stage is presented by the following equation:

$$EK_i = ek_i[de_i E_i^{-u_i} + dk_i K_i^{-u_i}]^{-1/u_i}, \tag{7}$$

$$de_i + dk_i = 1,$$

$$v_i = 1/(1+u_i)\text{; elasticity of substitution.}$$

The first-order condition for cost minimization yields the following equation.

$$E_i/K_i = h_i(PK_i/PE_i)^{v_i}, \quad h_i = (de_i/dk_i)^{v_i}. \tag{8}$$

We can estimate the elasticity of substitution between energy and capital, v_i, based on the log-linear form of the above first-order condition as follows:[4]

$$\ln(E_i/K_i) = \ln h_i + v_i \ln(PK_i/PE_i). \tag{9}$$

By applying the dual function to the CES function (7), we can define the price for the energy-capital aggregate input as

$$PEK_i = ek_i^{-1}[de_i^{v_i} PE_i^{1-v_i} + dk_i^{v_i} PK_i^{1-v_i}]^{1/(1-v_i)}. \tag{10}$$

The scale factor of the production function, ek_i, is again estimated by setting PEK_i to unity at the base year. Accordingly, the energy-capital aggregate input at constant price, EK_i, can be estimated as VEK_i/PEK_i.

The last aggregation stage gives us the estimates for the elasticities of substitution among M_i, EK_i, and L_i, and the rate of technical progress of the labor augmenting type. At this second aggregation level, the output of each industry is related to the above three inputs by the following CES production function:

$$X_i = x_i[dm_i M_i^{-r_i} + dek_i EK_i^{-r_i} + dl_i(L_i \cdot e^{\lambda_i t})^{-r_i}]^{-1/r_i}, \tag{11}$$

$$dm_i + dek_i + dl_i = 1$$

$$s_i = 1/(1+r_i)\text{; elasticity of substitution.}$$

The first order condition for cost minimization at the second stage is

$$M_i/X_i = x_i^{s_i-1} dm_i^{s_i}(P_i/PM_i)^{s_i} \tag{12}$$

$$EK_i/X_i = x_i^{s_i-1} dek_i^{s_i}(P_i/PEK_i)^{s_i} \tag{13}$$

$$L_i/X_i = x_i^{s_i-1} dl_i^{s_i}(P_i/W_i)^{s_i} \cdot \exp[(s_i-1)\lambda_i t]. \tag{14}$$

We incorporate two different chronological time trends t_1 and t_2 , reflecting the breakdown in technical progress after the first oil crisis of 1973. The elasticity of substitution, s_i and the rate of technical progress, λ_{1i} and λ_{2i}, can be estimated by the following log-linear form of the three first-order conditions:

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[4] It should be noted that the elasticity of substitution estimated by equation (9) is defined on the isoquant of the aggregated input EK_i. That is to say, it is not Allen's partial elasticity of substitution, which is defined on the isoquant of output X_i.

$$\ln(M_i/X_i) = s_i \ln(P_i/PM_i) + \beta_{M_i} \tag{15}$$

$$\ln(EK_i/X_i) = s_i \ln(P_i/PEK_i) + \beta_{EK_i} \tag{16}$$

$$\ln(L_i/X_i) = s_i \ln(P_i/W_i) + \gamma_{1i} t_1 + \gamma_{2i} t_2 + \beta_{L_i} \tag{17}$$

where

$$\beta_{M_i} = (s_i - 1)\ln x_i + s_i \ln dm_i,$$

$$\beta_{EK_i} = (s_i - 1)\ln x_i + s_i \ln dek_i,$$

$$\beta_{L_i} = (s_i - 1)\ln x_i + s_i \ln dl_i,$$

$$\gamma_{1i} = (s_i - 1)\lambda_{1i}, \text{ and}$$

$$\gamma_{2i} = (s_i - 1)\lambda_{2i}.$$

Under the assumption of weak separability, the price elasticities of the four factors are calculated in terms of the elasticities of each aggregation level and the relative shares of four inputs in the following way.[5] In the case of energy-capital separability, we can define the price elasticity of capital, K, with respect to energy price, PE ,as follows:

$$\begin{aligned} \varepsilon_{KE} = \frac{\partial \ln K}{\partial \ln PE} = & \left.\frac{\partial \ln K}{\partial \ln PE}\right|_{EK=const.} \\ & + \left.\frac{\partial \ln K}{\partial \ln EK} \cdot \frac{\partial \ln EK}{\partial \ln PEK} \cdot \frac{\partial \ln PEK}{\partial \ln PE}\right|_{X=const.} \end{aligned} \tag{18}$$

Equation (18) means that the total effect of the energy price change is the sum of the price effect, with EK being constant and the quantity effect owing to the change in aggregate price PEK induced by the change in PE. Following Berndt and Wood (1975), in what follows we call the first term *net elasticity* and the second term *expansion elasticity*. Also, Allen's partial elasticity of substitution between energy and capital can be expressed by dividing the right hand side of equation (18) by the relative share of capital input, S_E, that is to say,

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[5] In the discussion of elasticity for aggregated inputs, all the subscripts i showing industry will be eliminated for simplicity.

$$\sigma_{KE} = \frac{1}{S_E}\frac{\partial \ln K}{\partial \ln PE} = \frac{1}{S_E}\frac{\partial \ln K}{\partial \ln PE}\bigg|_{EK=const.} + \frac{1}{S_E}\frac{\partial \ln K}{\partial \ln EK}\cdot\frac{\partial \ln EK}{\partial \ln PEK}\cdot\frac{\partial \ln PEK}{\partial \ln PE}\bigg|_{X=const.} \tag{19}$$

For price elasticities both of energy and capital, and elasticity of substitution of the corresponding inputs, which are assumed to be weak-separable with respect to the prices other than *PE* or *PK*, it is clear that there is no net elasticity. They can simply be obtained by the elasticity of substitution at the second aggregation level, s, and the corresponding relative cost shares. For example, the price elasticity of energy with respect to non-energy material price is defined as

$$\varepsilon_{EM} = \frac{\partial \ln E}{\partial \ln EK}\cdot\frac{\partial \ln EK}{\partial \ln PM}\bigg|_{X=const.} \tag{20}$$

Accordingly, elasticity of substitution between energy and non-energy material can be expressed as

$$\sigma_{EM} = \frac{1}{S_M}\frac{\partial \ln E}{\partial \ln EK}\cdot\frac{\partial \ln EK}{\partial \ln PM}\bigg|_{X=const.} \tag{21}$$

Since the first term of the right hand side of (18) is the price elasticity of capital at the first aggregation level, it can be expressed by the elasticity of substitution between energy and capital, v, at the first aggregation level and the share of capital in aggregate input *EK*:

$$\frac{S_K}{S_E + S_K}\cdot v,$$

where S_K and S_E are the relative cost shares of capital and energy, respectively.

For the second term of the right hand side of (18), under the assumption of the homogeneity of the production function (7) and the unit cost function (10), we obtain

$$\frac{\partial \ln K}{\partial \ln EK} = 1, \quad \text{and} \quad \frac{\partial \ln PEK}{\partial \ln PE} = \frac{S_E}{S_E + S_K}.$$

Accordingly, the second term is expressed by the elasticity of substitution at the second aggregated level as

$$\varepsilon_{KE} = \frac{S_E}{S_E + S_K}v + S_E\left(1 - \frac{1}{S_E + S_K}\right)s, \text{ and} \tag{22}$$

$$\sigma_{KE} = \frac{1}{S_E + S_K}v + \left(1 - \frac{1}{S_E + S_K}\right)s \tag{23}$$

Applying the same idea to other combinations of input and price, we can easily obtain all the own and cross price elasticities and elasticity of substitution among all the inputs. The above discussion shows that the elasticities of substitution except for the inputs, which are assumed to be weakly separable, are simply the elasticity of substitution at the second aggregation level and always take positive value as long as the quasi-concavity condition of the production function is satisfied. Elasticity of substitution between the weakly separable inputs, however, can take either positive or negative value depending on the relative magnitude of the elasticity of substitution at both aggregation levels and the relative shares of four inputs.[6]

The same idea can be applied to the calculation of the price elasticities of the disaggregated input, $\partial \ln X_{ji} / \partial \ln PX_l$. In this case, we should also consider both net and expansion elasticities. For example, the elasticity of the demand for intermediate input from industy j with respect to price P_l for industry i $\partial \ln X_{ji} / \partial \ln PX_l$, $j \in j_e, l \in j_e$, and $j = l$, is expressed as

$$\begin{aligned} \varepsilon_{jl} &= \left. \frac{\partial \ln X_{ji}}{\partial \ln PX_l} \right|_{E_i = CONST.} \\ &+ \left. \frac{\partial \ln X_{ji}}{\partial \ln E_i} \cdot \frac{\partial \ln E_i}{\partial \ln PE_i} \cdot \frac{\partial \ln PE_i}{\partial \ln PX_l} \right|_{EK_i = CONST.} \\ &+ \left. \frac{\partial \ln X_{ji}}{\partial \ln E_i} \cdot \frac{\partial \ln E_i}{\partial \ln EK_i} \cdot \frac{\partial \ln EK_i}{\partial \ln PEK_i} \cdot \frac{\partial \ln PEK_i}{\partial \ln PE_i} \cdot \frac{\partial \ln PE_i}{\partial \ln PX_l} \right|_{X_i = CONST.} \end{aligned} \tag{24}$$

Since we assume the Cobb-Douglas production function for the aggregator of energy and non energy materials respectively, the elasticity of substitution at the individual industry level is always unity. Accordingly, equation (24) is reduced to

$$c_{li}(1 + \varepsilon_{EE}) - 1. \tag{25}$$

Every price elasticity of the disaggregated intermediate input can be expressed in terms of normalized input coefficient in value terms defined in equations (3) and (4) and the own and cross price elasticities of the four aggregated inputs. These price elasticities do not depend on the type of separability since the separability condition has already been taken into account in the calculation of the price elasticities of the aggregated inputs. It should be noted , however, that detailed classification is necessary for the corresponding input X_{ij} and the price PX_l. For every case, the formula of the price elasticity is shown in Table 2.

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[6] The separability is statistically tested by the likelihood ratio test. For the adopted combination of separable inputs, see Appendix B.

Table 2: The Formulae of the Price Elasticity ε_{jl}

(1)	$c_{li}(1+\varepsilon_{EE})-1$	for	$j \in j_e,\ l \in j_e,\ l = j$
(2)	$c_{li}(1+\varepsilon_{EE})$	for	$j \in j_e,\ l \in j_e,\ l \neq j$
(3)	$b_{li}\varepsilon_{EM}$	for	$j \in j_e,\ l \in j_m$
(4)	ε_{EL}	for	$j \in j_e,\ l = L$
(5)	ε_{EK}	for	$j \in j_e,\ l = K$
(6)	$c_{li}\varepsilon_{ME}$	for	$j \in j_m,\ l \in j_e$
(7)	$b_{li}(1+\varepsilon_{MM})-1$	for	$j \in j_m,\ l \in j_m,\ l = j$
(8)	$b_{li}(1+\varepsilon_{MM})$	for	$j \in j_m,\ l \in j_m,\ l \neq j$
(9)	ε_{ML}	for	$j \in j_m,\ l = L$
(10)	ε_{MK}	for	$j \in j_m,\ l = K$
(11)	$c_{li}\varepsilon_{LE}$	for	$j = L,\ l \in j_e$
(12)	$b_{li}\varepsilon_{LM}$	for	$j = L,\ l \in j_m$
(13)	ε_{LL}	for	$j = L,\ l = L$
(14)	ε_{LK}	for	$j = L,\ l = K$
(15)	$c_{li}\varepsilon_{KE}$	for	$j = K,\ l \in j_e$
(16)	$b_{li}\varepsilon_{KM}$	for	$j = K,\ l \in j_m$
(17)	ε_{KL}	for	$j = K,\ l = L$
(18)	ε_{KK}	for	$j = K,\ l = K$

3. The Estimated Results (1): the Aggregated Level

Table 3 presents the estimates of the own price elasticity of capital, ε_{KK}. First, the bottom row of the table[7] shows that the total manufacturing average of the own price elasticity of capital in terms of absolute value is highest (-0.618) in Korea and lowest (-0.245) in the United States, and that these averages are on the high side (-0.542 and -0.442) in Taiwan and Italy, and moderately lower (-0.284 and -0.296) in Japan and West Germany. Similar ordering is discerned in the own price elasticity of labor, ε_{LL}, which is shown in Table 4. It is highest (-0.712) in Korea and lowest (-0.225) in the United States, while it is on the high side (-0.586) in Taiwan, and moderately lower (-0.391, -0.273 and -0.265) in Italy, Japan and West Germany, respectively. These figures may reflect the high flexibility of labor adjustment in East Asian countries and the relatively low flexibility in developed countries. The country averages of estimates for each industry are also shown in the right column of the tables. The own price elasticity of capital varies between -0.6 and -0.2, except for the extremely low elasticity, -0.092, for nonferrous metal products. It should be noted, however, that this estimate is only for Germany and may be subject to country-specific estimation error, while other figures are averages of the country estimates. As for the estimates of ε_{LL}, they also vary between -0.6 and -0.2, but are relatively low for process industries like motor vehicles, leather, and furniture, while relatively high for processing industries like petroleum, pulp, and chemical industries.

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[7] The figures are the weighted average of the industry's estimates for each country with weights of the output in the base year.

Table 3: Own Price Elasticity of Capital, ε_{KK}

		USA	FRG	ITA	JPN	KOR	TWN	average
(1)	Food	-0.089	-0.178	-0.338	-0.294	-0.647	-0.403	-0.328
(2)	Beverages						-0.420	-0.420
(3)	Textile mill products	-0.427	-0.257	-0.414	-0.016	-0.634	-0.448	-0.366
(4)	Apparel	-0.172	-0.208				-0.460	-0.280
(5)	Pulp & paper products	-0.363	-0.281	-0.356	-0.373	-0.748	-0.708	-0.472
(6)	Printing & publishing	-0.148	-0.350					-0.249
(7)	Chemicals	-0.246	-0.470	-0.340	-0.296	-0.773	-0.417	-0.424
(8)	Petroleum & coal products	-0.160	-0.336		-0.090	-0.618	-0.297	-0.300
(9)	Rubber & plastics	-0.153	-0.045				-0.614	-0.271
(10)	Leather	-0.041	-0.251				-0.538	-0.277
(11)	Lumber & wood	-0.358	-0.082	-0.561			-0.431	-0.358
(12)	Furniture	-0.311						-0.311
(13)	Stone, clay, & glass	-0.076	-0.572	-0.586	-0.375	-0.602	-0.621	-0.472
(14)	Primary metals	-0.408	-0.511	-0.384	-0.299	-0.046	-0.759	-0.401
(15)	Nonferrous metals		-0.092					-0.092
(16)	Fabricated metal products	-0.247	-0.178		-0.228	-0.697	-0.055	-0.281
(17)	General machinery	-0.426	-0.291	-0.547	-0.516	-0.837	-0.457	-0.512
(18)	Electrical machinery	-0.411	-0.131		-0.503	-0.755	-0.864	-0.533
(19)	Transportation equipment	-0.141	-0.013		-0.144	-0.715	-0.564	-0.315
(20)	Motor vehicles	-0.188	-0.269					-0.229
(21)	Precision instruments	-0.083	-0.374		-0.296	-0.829		-0.396
(22)	Miscellaneous manufacturing	-0.087	-0.381	-0.415	-0.321	-0.681	-0.765	-0.441
(23)	Total manufacturing	-0.245	-0.296	-0.442	-0.284	-0.618	-0.542	-0.403

Table 4: Own Price Elasticity of Labor, ε_{LL}

		USA	FRG	ITA	JPN	KOR	TWN	average
(1)	Food	-0.080	-0.177	-0.339	-0.290	-0.743	-0.418	-0.341
(2)	Beverages						-0.935	-0.935
(3)	Textile mill products	-0.338	-0.204	-0.348	-0.120	-0.734	-0.461	-0.368
(4)	Apparel	-0.126	-0.123				-0.456	-0.235
(5)	Pulp & paper products	-0.340	-0.359	-0.308	-0.360	-0.884	-0.756	-0.501
(6)	Printing & publishing	-0.102	-0.281					-0.192
(7)	Chemicals	-0.228	-0.549	-0.301	-0.448	-0.910	-0.465	-0.484
(8)	Petroleum & coal products	-0.667	-0.240		-0.448	-0.976	-0.465	-0.559
(9)	Rubber & plastics	-0.106	-0.040				-0.654	-0.267
(10)	Leather	-0.027	-0.159				-0.545	-0.244
(11)	Lumber & wood	-0.281	-0.083	-0.534			-0.464	-0.341
(12)	Furniture	-0.240						-0.240
(13)	Stone, clay, & glass	-0.023	-0.572	-0.613	-0.410	-0.723	-0.774	-0.519
(14)	Primary metals	-0.488	-0.511	-0.323	-0.280	-0.049	-0.920	-0.429
(15)	Nonferrous metals		-0.025					-0.025
(16)	Fabricated metal products	-0.168	-0.131		-0.452	-0.714	-0.060	-0.305
(17)	General machinery	-0.294	-0.198	-0.437	-0.273	-0.823	-0.440	-0.411
(18)	Electrical machinery	-0.307	-0.074		-0.475	-0.829	-0.868	-0.511
(19)	Transportation equipment	-0.096	-0.009		-0.130	-0.720	-0.544	-0.300
(20)	Motor vehicles	-0.171	-0.212					-0.192
(21)	Precision instruments	-0.051	-0.320		-0.200	-0.839		-0.353
(22)	Miscellaneous manufacturing	-0.066	-0.295	-0.376	-0.207	-0.646	-0.701	-0.382
(23)	Total manufacturing	-0.225	-0.265	-0.391	-0.273	-0.712	-0.586	-0.409

Table 5: Own Price Elasticity of Energy, ε_{EE}

		USA	FRG	ITA	JPN	KOR	TWN	average
(1)	Food	-0.684	-0.960	-0.966	-0.542	-0.971	-0.998	-0.854
(2)	Beverages						-0.991	-0.991
(3)	Textile mill products	-0.445	-0.370	-0.304	-0.777	-0.582	-0.441	-0.487
(4)	Apparel	-0.169	-0.623				-0.973	-0.588
(5)	Pulp & paper products	-0.285	-0.295	-0.402	-0.399	-0.732	-0.377	-0.415
(6)	Printing & publishing	-0.434	-0.580					-0.507
(7)	Chemicals	-0.161	-0.471	-0.580	-0.292	-0.779	-0.777	-0.510
(8)	Petroleum & coal products	-0.218	-0.158		-0.087	-0.614	-0.286	-0.273
(9)	Rubber & plastics	-0.181	-0.919				-0.578	-0.559
(10)	Leather	-0.602	-0.677				-0.640	-0.640
(11)	Lumber & wood	-0.473	-0.951	-0.446			-0.375	-0.561
(12)	Furniture	-0.222						-0.222
(13)	Stone, clay, & glass	-0.164	-0.663	-0.587	-0.387	-0.561	-0.672	-0.506
(14)	Primary metals	-0.301	-0.827	-0.737	-0.330	-0.758	-0.749	-0.617
(15)	Nonferrous metals		-0.047					-0.047
(16)	Fabricated metal products	-0.252	-0.305		-0.520	-0.670	-0.954	-0.540
(17)	General machinery	-0.633	-0.495	-0.466	-0.407	-0.885	-0.434	-0.553
(18)	Electrical machinery	-0.291	-0.429		-0.651	-0.715	-0.986	-0.614
(19)	Transportation equipment	-0.494	-0.943		-0.675	-0.787	-0.426	-0.665
(20)	Motor vehicles	-0.227	-0.451					-0.339
(21)	Precision instruments	-0.601	-0.976		-0.593	-0.845		-0.754
(22)	Miscellaneous manufacturing	-0.639	-0.627	-0.352	-0.432	-0.729	-0.747	-0.588
(23)	Total manufacturing	-0.386	-0.632	-0.541	-0.446	-0.746	-0.707	-0.576

Table 6: Own Price Elasticity of Non-energy Materials, ε_{MM}

		USA	FRG	ITA	JPN	KOR	TWN	average
(1)	Food	-0.032	-0.094	-0.141	-0.117	-0.278	-0.091	-0.125
(2)	Beverages						-0.655	-0.655
(3)	Textile mill products	-0.175	-0.126	-0.233	-0.048	-0.236	-0.175	-0.166
(4)	Apparel	-0.071	-0.070				-0.171	-0.104
(5)	Pulp & paper products	-0.210	-0.161	-0.210	-0.136	-0.315	-0.345	-0.230
(6)	Printing & publishing	-0.089	-0.212					-0.151
(7)	Chemicals	-0.121	-0.362	-0.526	-0.204	-0.400	-0.395	-0.335
(8)	Petroleum & coal products	-0.613	-0.142		-0.813	-0.315	-0.918	-0.560
(9)	Rubber & plastics	-0.088	-0.107				-0.256	-0.150
(10)	Leather	-0.025	-0.105				-0.181	-0.104
(11)	Lumber & wood	-0.211	-0.093	-0.319			-0.199	-0.206
(12)	Furniture	-0.147						-0.147
(13)	Stone, clay, & glass	-0.019	-0.465	-0.517	-0.251	-0.519	-0.527	-0.383
(14)	Primary metals	-0.251	-0.303	-0.184	-0.099	-0.131	-0.315	-0.214
(15)	Nonferrous metals		-0.008					-0.008
(16)	Fabricated metal products	-0.135	-0.089		-0.298	-0.256	-0.074	-0.170
(17)	General machinery	-0.238	-0.139	-0.296	-0.118	-0.379	-0.165	-0.223
(18)	Electrical machinery	-0.245	-0.055		-0.208	-0.286	-0.282	-0.215
(19)	Transportation equipment	-0.066	-0.061		-0.064	-0.273	-0.230	-0.139
(20)	Motor vehicle	-0.074	-0.103					-0.089
(21)	Precision instruments	-0.076	-0.317		-0.124	-0.336		-0.213
(22)	Miscellaneous manufacturing	-0.058	-0.204	-0.214	-0.107	-0.229	-0.351	-0.194
(23)	Total manufacturing	-0.148	-0.177	-0.297	-0.177	-0.280	-0.300	-0.230

Tables 5 and 6 present the estimates of the own price elasticity of two types of materials, energy and non-energy. For total manufacturing, the magnitudes of elasticity of energy and non-energy materials are on the whole in an order similar to that in the case of the own price elasticities of capital and labor. For energy materials, the own price elasticity is highest (-0.746) in Korea, second highest (-0.707) in Taiwan, lowest (-0.386) in the United States, third (-0.632) in Germany, and moderately higher (-0.541 and -0.446) in Italy and Japan. For non-energy materials, the differences in own price elasticity among countries are not as large as those in other factors. Similar orderings of magnitudes are observed, however, with the highest (-0.300) in Taiwan, the second and third highest (-0.297 and -0.280) in Italy and Korea, respectively, followed by the lower magnitudes (-0.177) in both West Germany and Japan, and the lowest (-0.148) in the United States.

The findings above seem to suggest that expect for Japan East Asian countries belong to high elasticity and Western countries to low elasticity groups. Japan may be classified as belonging to the Western group, while Italy falls between East Asian and Western countries.

The method also enables us to obtain estimates for Allen's partial elasticity of substitution between capital and energy, σ_{KE}. The elasticity of substitution between capital and energy is a very important concept in light of the fact that two big oil crises occurred in our sample period—in 1973 and in 1979—and that the repercussions of these crises even now have a significant effect on the growth rate of all three Asian countries. The elasticity of substitution between capital and energy measures the proportional change in the capital-energy ratio induced by the proportional change in the relative prices between energy and capital. It may be positive or negative, depending on whether capital and energy are substitutes or complements. If both factors are substitutes, a rise in oil price leads to an increase in capital-energy ratio, resulting in an increase in investment, which is favorable to economic growth. In contrast, if both factors are complements, a rise of oil price leads to the scrapping-up of, or a freeze in new investment in oil-using equipment, resulting in a decline in the production of oil-consuming products, or in a reduction in investment in oil consuming equipment.

Table 7 shows estimates for the elasticity of substitution between capital and energy. The figures for total manufacturing indicate that the values are positive and very large (0.947 and 0.802) for Germany and Japan; positive and relatively large (0.288) for Korea; slightly negative (-0.089) for the United States; and positive (0.094) for Taiwan. For Italy the figure is negative and relatively large (-0.375), implying a significant complementary relationship between capital and energy. Since energy consumption depended heavily on crude oil in Japan before 1973 and domestic production of oil is practically zero, the oil crises in 1973 and 1979 seriously affected Japanese industrial production. It should be noted, however, that the Japanese economy recovered relatively quickly from the recession and has maintained an average GDP growth rate of around 4% since the oil crisis, largely because fixed investment did not fall drastically and new investment was stimulated in energy-saving plants and equipment, feature of the Japanese economy apparently reflected in its high positive elasticity of substitution between capital and energy.

Table 7: Elasticity of Substitution between Capital and Energy, σ_{KE}

		USA	FRG	ITA	JPN	KOR	TWN	average
(1)	Food	0.096	0.203	0.391	1.438	1.553	0.455	0.689
(2)	Beverages						1.000	1.000
(3)	Textile mill products	0.274	0.925	-1.244	0.017	-0.697	-0.063	-0.131
(4)	Apparel	-0.070	3.077				-2.285	0.241
(5)	Pulp & paper products	-0.831	-0.654	0.315	0.595	-0.607	0.704	-0.080
(6)	Printing & publishing	0.167	1.364					0.766
(7)	Chemicals	0.296	0.041	0.373	-0.349	0.556	0.528	0.241
(8)	Petroleum & coal products	-0.126	0.430		0.104	-0.638	0.483	0.051
(9)	Rubber & plastics	0.171	0.056				-1.753	-0.509
(10)	Leather	0.042	2.884				0.773	1.233
(11)	Lumber & wood	0.825	0.105	-1.037			-0.359	-0.117
(12)	Furniture	-1.585						-1.585
(13)	Stone, clay, & glass	0.988	0.654	0.028	-0.301	0.557	0.612	0.423
(14)	Primary metals	-2.994	0.563	-0.139	0.677	0.052	-0.095	-0.323
(15)	Nonferrous metals		0.448					0.448
(16)	Fabricated metal products	0.064	0.964		-9.948	-0.552	0.072	-1.880
(17)	General machinery	1.845	1.868	-0.856	0.929	1.000	-0.300	0.748
(18)	Electrical machinery	-1.054	2.006		0.586	-0.282	1.000	0.451
(19)	Transportation equipment	0.148	0.013		0.161	0.725	-1.392	-0.069
(20)	Motor vehicles	0.316	1.711					1.014
(21)	Precision instruments	0.098	0.494		2.907	0.131		0.908
(22)	Miscellaneous manufacturing	0.097	1.683	-0.580	2.658	0.590	-0.186	0.710
(23)	Total manufacturing	-0.089	0.947	-0.375	0.802	0.288	0.094	0.278

Generally speaking, a higher own price elasticity means that the production structure is flexible and sensitive to changes in the economic structure. Therefore, one can argue that a production structure with higher price elasticity may be at a competitive advantage in the international market since it adjusts more quickly to the optimal position from the viewpoint of cost minimization. Indeed, it is found from empirical results on the estimates of price elasticity that Korea and Taiwan occupy the most favorable position in the international market, followed by Japan, West Germany and Italy.

As for the ordering of the magnitude of price elasticity, we can emphasize the following three aspects of the production structure. First of all, the magnitude of price elasticity depends on the degree of mechanization in the production process. The more mechanized the production technique is, the more rigid is the value of the input coefficient. For example, if a highly mechanized machine is operated by simple, unskilled labor, the capital-labor ratio may be rigid. Complete automation in the production process requires only a very rigid number of laborers, and thereby the capital-labor ratio is less flexible, at least in the short run.

Also important in production structure are employment practices or special features of the industrial organization of each country. One may be bothered by the paradoxical fact that the price elasticity of labor demand is higher in Japan than in the United States in spite of what is widely known as Japan's life-time employment system, which could be expected to make the price elasticity of labor demand smaller in Japan than in the United States. The difference, however, can be explained by the fact that the production activities of the large incorporated firms which dominate the Japanese production system are often diversified across industries, facilitating the relatively smooth movement of capital and labor across industries, even if these remain within the same firm. This is especially true for the labor transfer from a less profitable activity to a more profitable one within the same firm.

Reflected in the estimated values of the price flexibility and the elasticity of substitution, this flexibility has greatly contributed to the strong competitive power of Japanese firms during several phases of structural change since the oil crisis.

Third, it is true that while Japan produces a large number of goods in highly mechanized workshops, it also has managed to support a substantial number of small firms. The role of such small firms has been to provide intermediate products to large incorporated firms. The production structure of small firms is less mechanized and their employment practices are less modernized, since these firms include a large number of self-employed and family workers who comprise a marginal sector in the fluctuation of employment. This contingent of small firms has made the Japanese production structure more adaptable to changes in the economic situation, with their smoother movement of capital and labor than in the highly mechanized larger incorporated firms.

In this context, we also have to take into account the existence of disguised unemployment in East Asian countries. If the market in an urban area is short of labor, wages tend to rise and laborers move to urban areas, or to the industrial sector from the primary sector. On the other hand, if the market in an urban area has the surplus of labor, laborers will move back to the rural area, implying flexibility of labor input coefficients both in agriculture and industry. Thus labor input coefficients are more flexible in countries with a large share of unincorporated firms. Krugman (1994) also contends that Asia's high economic growth can be explained not by substantial technological progress but by the utilization of a relatively abundant labor force, a view consistent with our results. The higher value of Italy's input coefficients may be ascribed to the fact that the Italian economy has retained a larger share of unincorporated firms than other Western economies referred to here.[8]

4. Estimated Results (2): The Disaggregated Level

Table 9 presents a summary of the estimated price elasticity of the factor demand, which is presented by the element of the Jacobian matrix[9] in elasticity terms,

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[8] A more detailed and exhaustive discussion on this aspect is found in Saito(2000).

[9] For the economic implications of the Jacobian matrix and its application to the inter-industry study economy as a whole, see Tokutsu (1994). It should be noted, however, that the Jacobian matrix in this paper is derived based on the cost minimization assumption with a given level of output, while that in Tokutsu (1994) is derived based on the short-run profit maximization assumption with a given level of capital stock. The latter is easily converted from the former by comparing the Slutsky equations of the first order condition for both assumptions. The method of conversion is explained in detail in the

$\partial \ln X_{ji} / \partial \ln P_k$, for the individual industries of all six countries:[10]

1.	United States	(USA)
2.	West Germany	(Europe)
3.	Italy	(Europe)
4.	Japan	(East Asia)
5.	Korea	(East Asia)
6.	Taiwan	(East Asia)

In the tables, each of six columns gives the estimates of the six countries, respectively. Each manufacturing industry occupies about 12 rows. For example, the first four rows of "1. Food" summarize the diagonal elements of the Jacobian matrix of the price elasticities; the figure in row (1), -0.753 for the United States, implies that demand for the factor input X_{55} will decrease by 0.753 % when the output price of food industry increases by a unit %. The figures in rows (2) to (4) present the average and range of all the diagonal elements. Rows (5) and (6) are the own price elasticity of the demand for labor and capital, respectively. Rows (7) to (9) give the average and range of all the off-diagonal elements. It should be noted that the values in (7) are usually small in the Jacobian matrix. The rows below (10) present the price elasticity among closely related industries in the factor demand. For example, the agriculture industry provides the food industry with its most important factor input. Thus, the elasticity of the demand for agriculture products with respect to the price of food products, 0.247 for the United States, shown in row (11), is significantly large compared with other off-diagonal elements.

The last nine rows of Table 9 (below the results for individual industries) give the average and the range of the elasticity for total manufacturing. In the United States the average of all diagonals (row (2)) is close to unity, and the average of own diagonals (row (1)), -0.738, is significantly less than unity (in absolute values). Own price elasticities of labor and capital (row (5) and (6)) are on average -0.225 and -0.245 respectively. Finally, the average of all off-diagonals, row (7), is rather close to zero.

Now let us compare elasticities among the six countries. First of all, it must be stressed that our estimates of price elasticities are fairly stable. As shown in rows (2) to (4) and (7) to (9) in total manufacturing, the average and range of both diagonals and off-diagonals are considerably stable: all the values lie between 0 and unity. This finding may suggest the effectiveness of our method of estimation, especially in view of the well-known fact that the parameter estimates of the transcendental logarithmic production functions are sometimes very unstable.[11]

Appendix to Tokutsu (1999). It is found that in general, price elasticities obtained from the Jacobian matrix with a given output is larger than those with a given level of capital stock.

[10] The statistics of the regression and the discussions of their economic implications are presented in our previous papers: Saito and Tokutsu(1992a) for West Germany, the US, and Japan; (1992b) for Taiwan; and (1991) for Korea. Sources for the data and the sample period are also provided in the corresponding papers.

[11] See, for example, Kuroda, Yoshioka, and Jorgenson (1984).

Table 9: Representative Elements of the Jacobian Matrix

	USA	FRG	ITA	JPN	KOR	TWN
1. Food						
(1)Own-diagonals	-0.75330	-0.70421	-0.79695	-0.83003	-0.85949	-0.83243
(2)All-diagonals (average)	-0.95571	-0.96359	-0.95036	-0.94638	-0.96736	-0.96204
(3) (maximum)	-0.61412	-0.64900	-0.50248	-0.51774	-0.51928	-0.39612
(4) (minimum)	-1.00000	-0.99990	-0.99957	-0.99998	-0.99996	-0.99996
(5)Labor	-0.08001	-0.17741	-0.33857	-0.29001	-0.74310	-0.41796
(6)Capital	-0.08939	-0.17546	-0.33775	-0.29355	-0.64727	-0.40327
(7)All off-diagonals (average)	0.03332	0.03641	0.04964	0.03377	0.03103	0.03800
(8) (maximum)	0.38588	0.35100	0.49752	0.48226	0.48072	0.60442
(9) (minimum)	0.00000	0.00010	0.00043	0.00000	0.00003	0.00004
Input / Price						
(10) Agriculture / Agriculture	-0.61412	-0.64900	-0.50248	-0.51774	-0.51928	-0.39612
(11) Agriculture / Food	0.24670	0.29599	0.20305	0.16997	0.14051	0.16757
(12) Food / Agriculture	0.38588	0.35100	0.49752	0.48226	0.48072	0.60389
2. Beverage						
(1)Own-diagonals						-0.93710
(2) All-diagonals (average)						-0.98458
(3) (maximum)						-0.93710
(4) (minimum)						-0.99999
(5)Labor						-0.93460
(6)Capital						-0.42000
(7)All off-diagonals (average)						0.01542
(8) (maximum)						0.06290
(9) (minimum)						0.00001
Input / Price						
(10) Food / Food						-0.95010
(11) Food / Beverage						0.06290
(12) Agriculture / Textiles						0.04990
3. Textile						
(1)Own-diagonals	-0.64521	-0.73916	-0.52875	-0.56914	-0.70481	-0.59661
(2) All-diagonals (average)	-0.94888	-0.94217	-0.91392	-0.94656	-0.94627	-0.94674
(3) (maximum)	-0.59179	-0.60254	-0.52875	-0.56914	-0.70481	-0.59661
(4) (minimum)	-0.99995	-0.99940	-0.99955	-0.99996	-0.99997	-0.99999
(5)Labor	-0.33789	-0.20439	-0.34780	-0.01179	-0.73386	-0.46138
(6)Capital	-0.42724	-0.25656	-0.41351	-0.01644	-0.63413	-0.44780
(7)All off-diagonals (average)	0.03013	0.03265	0.04548	0.04485	0.03720	0.03192
(8) (maximum)	0.40822	0.39746	0.47125	0.43086	0.29520	0.40339
(9) (minimum)	0.00002	0.00010	0.00016	0.00003	0.00002	0.00000
Input / Price						
(10) Agriculture / Agriculture	-0.97068	-0.99541	-0.96717	-0.86999	-0.87266	-0.92942
(11) Textile / Agriculture	0.00440	0.02370				0.00247
(12) Agriculture / Textiles	0.35479	0.26084	0.47125	0.43086	0.29520	0.40339

Table 9: (continued) Representative Elements of Jacobian Matrix

		USA	FRG	ITA	JPN	KOR	TWN
4. Apparel							
(1)Own-diagonals		-0.72984	-0.95281				-0.94303
(2) All-diagonals	(average)	-0.93479	-0.94772				-0.93687
(3)	(maximum)	-0.44854	-0.53707				-0.46360
(4)	(minimum)	-0.99998	-0.99989				-0.99999
(5)Labor		-0.12577	-0.12330				-0.45576
(6)Capital		-0.17237	-0.20762				-0.45984
(7)All off-diagonals	(average)	0.03335	0.03443				0.03662
(8)	(maximum)	0.55147	0.46293				0.53641
(9)	(minimum)	0.00000	0.00001				0.00000
Input / Price							
(10)	Textiles / Textiles	-0.64274	-0.53702				-0.46360
(11)	Textiles / Apparel	0.27016	0.04719				0.05697
(12)	Apparel / Textiles	0.35726	0.46293				0.53641
5. Paper & pulp							
(1)Own-diagonals		-0.63462	-0.73732	-0.58901	-0.47501	-0.52643	-0.58155
(2) All-diagonals	(average)	-0.94812	-0.94064	-0.92734	-0.93897	-0.95859	-0.96695
(3)	(maximum)	-0.59552	-0.64106	-0.58901	-0.47501	-0.52643	-0.58155
(4)	(minimum)	-0.99998	-0.99971	-0.99944	-1.00000	-0.99998	-0.99998
(5)Labor		-0.34041	-0.35926	-0.53419	-0.35922	-0.88399	-0.75559
(6)Capital		-0.36346	-0.28060	-0.56061	-0.37272	-0.74809	-0.70772
(7)All off-diagonals	(average)	0.02759	0.03349	0.04234	0.03625	0.03424	0.02718
(8)	(maximum)	0.40448	0.35894	0.41100	0.52499	0.47357	0.41846
(9)	(minimum)	0.00001	0.00010	0.00033	0.00000	0.00002	0.00002
Input / Price							
(10)	Pulp / Printing	-0.99950	-0.96937	-0.98278	-0.99548	-0.97537	-0.98968
(11)	Pulp / Pulp	0.36538	0.26268	0.41100	0.52499	0.47357	0.41846
(12)							
6. Printing & publishing							
(1)Own-diagonals		-0.83965	-0.91619				
(2) All-diagonals	(average)	-0.94319	-0.95169				
(3)	(maximum)	-0.64438	-0.71750				
(4)	(minimum)	-0.99996	-0.99950				
(5)Labor		-0.10180	-0.28095				
(6)Capital		-0.14813	-0.35041				
(7)All off-diagonals	(average)	0.03439	0.03029				
(8)	(maximum)	0.35562	0.28250				
(9)	(minimum)	0.00002	0.00003				
Input / Price							
(10)	Pulp / Printing	0.16036	0.08381				
(11)	Pulp / Pulp	-0.71771	-0.78379				
(12)							

Table 9: (continued) Representative Elements of Jacobian Matrix

	USA	FRG	ITA	JPN	KOR	TWN
7. Chemicals						
(1)Own-diagonals	-0.59042	-0.70688	-0.71527	-0.50380	-0.57121	-0.59614
(2) All-diagonals (average)	-0.93864	-0.95675	-0.94736	-0.93984	-0.96432	-0.96818
(3) (maximum)	-0.59042	-0.64168	-0.71527	-0.50380	-0.57121	-0.59614
(4) (minimum)	-0.99993	-0.99991	-0.99891	-0.99999	-0.99989	-0.99997
(5)Labor	-0.22833	-0.54937	-0.30080	-0.44749	-0.90991	-0.46519
(6)Capital	-0.24565	-0.47020	-0.33953	-0.29631	-0.77309	-0.41696
(7)All off-diagonals (average)	0.03039	0.02755	0.05264	0.03437	0.03287	0.03181
(8) (maximum)	0.40958	0.35832	0.28473	0.49621	0.42879	0.40386
(9) (minimum)	0.00000	0.00004	0.00109	0.00000	0.00011	0.00004
Input / Price						
(10) Agriculture / Agriculture	-0.99538	-0.99240	-0.99601	-0.99845	-0.97868	-0.99471
(11) Agriculture / Chemicals	0.40958	0.29312	0.28473	0.49621	0.42879	0.40386
(12)						
8. Petroleum & coal products						
(1)Own-diagonals	-0.92034	-0.22092		-0.94130	-0.88348	-0.76211
(2) All-diagonals (average)	-0.95825	-0.93462		-0.95415	-0.95343	-0.96682
(3) (maximum)	-0.32292	-0.22092		-0.15233	-0.36215	-0.53584
(4) (minimum)	-0.99998	-0.99985		-1.00000	-1.00000	-1.00000
(5)Labor	-0.66746	-0.24022		-0.10158	-0.97613	-0.46523
(6)Capital	-0.15983	-0.33637		-0.08996	-0.61765	-0.29726
(7)All off-diagonals (average)	0.02936	0.03618		0.04081	0.03693	0.03320
(8) (maximum)	0.67708	0.77908		0.84768	0.63785	0.46448
(9) (minimum)	0.00001	0.00002		0.00000	0.00000	0.00000
Input / Price						
(10) Mining / Mining	-0.32292	-0.98197		-0.15233	-0.75460	-0.53584
(11) Mining / Petroleum products	0.07966	0.77910		0.05870	0.11653	0.23783
(12) Petroleum products / Mining	0.67708	0.01803		0.84768	0.24540	0.46416
9. Rubber products						
(1)Own-diagonals	-0.91028	-0.86914				-0.87267
(2) All-diagonals (average)	-0.93818	-0.96394				-0.94581
(3) (maximum)	-0.49485	-0.77764				-0.65347
(4) (minimum)	-0.99997	-0.99970				-0.99994
(5)Labor	-0.10598	-0.04016				-0.65416
(6)Capital	-0.15256	-0.04463				-0.74941
(7)All off-diagonals (average)	0.03163	0.03606				0.03183
(8) (maximum)	0.50515	0.22236				0.34653
(9) (minimum)	0.00000	0.00030				0.00002
Input / Price						
(10) Agriculture / Chemicals	0.43086	0.22236				0.24549
(11) Agriculture / Rubber	0.08972	0.13069				0.12733
(12) Rubber / Chemicals	0.43086	0.22236				0.24549

Table 9: (continued) Representative Elements of Jacobian Matrix

	USA	FRG	ITA	JPN	KOR	TWN
10. Leather products						
(1)Own-diagonals	-0.66457	-0.65906				-0.78513
(2) All-diagonals (average)	-0.94718	-0.95127				-0.95084
(3) (maximum)	-0.66457	-0.65906				-0.77718
(4) (minimum)	-0.99982	-0.99849				-0.99996
(5)Labor	-0.02674	-0.15908				-0.54466
(6)Capital	-0.04099	-0.25055				-0.53760
(7)All off-diagonals (average)	0.03724	0.03320				0.03377
(8) (maximum)	0.33543	0.34094				0.22282
(9) (minimum)	0.00010	0.00008				0.00002
Input / Price						
(10) Chemicals / Leather	0.33543	0.34094				0.21487
(11)						
(12)						
11. Wood product						
(1)Own-diagonals	-0.60969	-0.69781	-0.53953			-0.74792
(2) All-diagonals (average)	-0.95300	-0.96459	-0.92285			-0.94296
(3) (maximum)	-0.60969	-0.69781	-0.53953			-0.56604
(4) (minimum)	-0.99991	-0.99992	-0.99891			-0.99990
(5)Labor	-0.28125	-0.08327	-0.30836			-0.46386
(6)Capital	-0.35836	-0.08221	-0.35599			-0.43075
(7)All off-diagonals (average)	0.02756	0.03541	0.04281			0.03236
(8) (maximum)	0.39031	0.30219	0.46047			0.43396
(9) (minimum)	0.00002	0.00008	0.00031			0.00003
Input / Price						
(10) Wood / Construction	0.00642	0.00326	0.01524			0.00154
(11)						
(12)						
12. Furniture						
(1)Own-diagonals	-0.99301					
(2) All-diagonals (average)	-0.93960					
(3) (maximum)	-0.47535					
(4) (minimum)	-0.99980					
(5)Labor	-0.23983					
(6)Capital	-0.31121					
(7)All off-diagonals (average)	0.03120					
(8) (maximum)	0.52465					
(9) (minimum)	0.00004					
Input / Price						
(10) Leather / Furniture	0.00699					
(11) Wood / Furniture	0.00699					
(12) Wood / Wood	-0.86507					

Table 9: (continued) Representative Elements of Jacobian Matrix

	USA	FRG	ITA	JPN	KOR	TWN
13. Stone, clay and glasses						
(1)Own-diagonals	-0.75492	-0.78768	-0.96695	-0.81659	-0.87214	-0.87172
(2) All-diagonals (average)	-0.93509	-0.96771	-0.94733	-0.94325	-0.96000	-0.96662
(3) (maximum)	-0.42216	-0.78768	-0.83833	-0.67900	-0.67912	-0.86741
(4) (minimum)	-0.99990	-0.99988	-0.99900	-0.99992	-0.99999	-0.99997
(5)Labor	-0.02261	-0.56274	-0.61257	-0.40973	-0.72264	-0.77427
(6)Capital	-0.07590	-0.57229	-0.58568	-0.37471	-0.60199	-0.62127
(7)All off-diagonals (average)	0.03349	0.02241	0.03552	0.03367	0.03078	0.02646
(8) (maximum)	0.57784	0.21232	0.16167	0.32100	0.32088	0.13259
(9) (minimum)	0.00000	0.00007	0.00070	0.00003	0.00001	0.00003
Input / Price						
(10) Mining / Electricity	0.00116	0.04007	0.03042	0.03060	0.05566	0.04568
(11) Mining / Petroleum products	0.00040	0.03116	0.03664	0.03790	0.16699	0.06444
(12)						
14. Primary metal						
(1)Own-diagonals	-0.62610	-0.68403	-0.95859	-0.30456	-0.32989	-0.49649
(2) All-diagonals (average)	-0.95171	-0.96895	-0.91513	-0.93455	-0.95169	-0.96176
(3) (maximum)	-0.57300	-0.68403	-0.38911	-0.30456	-0.32989	-0.49649
(4) (minimum)	-0.99999	-0.99982	-0.99976	-1.00000	-1.00000	-0.99999
(5)Labor	-0.48829	-0.48327	-0.32332	-0.28923	-0.04908	-0.88522
(6)Capital	-0.40776	-0.51118	-0.38381	-0.29918	-0.04620	-0.73817
(7)All off-diagonals (average)	0.02641	0.03105	0.04716	0.03746	0.04290	0.03093
(8) (maximum)	0.42700	0.31597	0.61090	0.69544	0.67011	0.50351
(9) (minimum)	0.00001	0.00018	0.00008	0.00000	0.00000	0.00001
Input / Price						
(10) Mining / Primary Metals	0.37390	0.31597	0.04141	0.69544	0.67011	0.50351
(11) Mining / Electricity	0.02019	0.06639	0.06450	0.13849	0.03838	0.03142
(12)						
15. Nonferrous metal						
(1)Own-diagonals		-0.70221				
(2)All-diagonals (average)		-0.93054				
(3) (maximum)		-0.23037				
(4) (minimum)		-0.99978				
(5)Labor		-0.02448				
(6)Capital		-0.09182				
(7)All off-diagonals (average)		0.03423				
(8) (maximum)		0.76963				
(9) (minimum)		0.00000				
Input / Price						
(10) Mining / Nonferrous Metals		0.27799				
(11) Mining / Electricity		0.00340				
(12)						

Table 9: (continued) Representative Elements of Jacobian Matrix

	USA	FRG	ITA	JPN	KOR	TWN
16. Fabricated metal products						
(1)Own-diagonals	-0.91875	-0.93126		-0.93857	-0.94477	-0.88772
(2) All-diagonals (average)	-0.94025	-0.94263		-0.94373	-0.95330	-0.94646
(3) (maximum)	-0.44270	-0.56476		-0.56452	-0.56103	-0.42893
(4) (minimum)	-0.99998	-0.99994		-0.99997	-0.99998	-0.99993
(5)Labor	-0.16822	-0.13056		-0.45241	-0.71373	-0.06024
(6)Capital	-0.24725	-0.17748		-0.22780	-0.69718	-0.15311
(7)All off-diagonals (average)	0.03120	0.03134		0.03498	0.03434	0.04177
(8) (maximum)	0.55730	0.43524		0.43548	0.43897	0.57107
(9) (minimum)	0.00000	0.00001		0.00002	0.00001	0.00000
Input / Price						
(10) Primary Metals / Fab. Metals	0.08125	0.06874		0.06143	0.05523	0.11228
(11) Primary Metals / Machinery	0.06155	0.02938		0.01057	0.02263	0.01239
(12)						
17. Machinery						
(1)Own-diagonals	-0.77017	-0.72538	-0.69107	-0.61019	-0.83228	-0.85865
(2) All-diagonals (average)	-0.96237	-0.95122	-0.92721	-0.92975	-0.96801	-0.94160
(3) (maximum)	-0.74679	-0.72538	-0.69107	-0.58599	-0.77435	-0.55638
(4) (minimum)	-0.99999	-0.99997	-0.99945	-0.99985	-1.00000	-0.99996
(5)Labor	-0.29356	-0.19800	-0.43735	-0.27334	-0.82285	-0.44009
(6)Capital	-0.42599	-0.29131	-0.54673	-0.31584	-0.83666	-0.45687
(7)All off-diagonals (average)	0.02460	0.02951	0.04206	0.04057	0.02852	0.03489
(8) (maximum)	0.25321	0.27462	0.30893	0.41402	0.22565	0.44362
(9) (minimum)	0.00000	0.00001	0.00027	0.00004	0.00000	0.00002
Input / Price						
(10) Primary Metals / Machinery	0.22983	0.27462	0.30893	0.38981	0.16772	0.14135
(11) Fab. Metals /Machinery	0.22983	0.27462		0.38981	0.16772	0.14135
(12)						
18. Electrical machinery						
(1)Own-diagonals	-0.75257	-0.64458		-0.68625	-0.64090	-0.60240
(2) All-diagonals (average)	-0.95119	-0.94586		-0.94566	-0.95654	-0.97072
(3) (maximum)	-0.45104	-0.64458		-0.68625	-0.64090	-0.60240
(4) (minimum)	-0.99997	-0.99988		-1.00000	-1.00000	-0.99999
(5)Labor	-0.30696	-0.07442		-0.47463	-0.82868	-0.86760
(6)Capital	-0.41083	-0.13093		-0.50252	-0.75462	-0.86440
(7)All off-diagonals (average)	0.02518	0.03180		0.03750	0.03269	0.02928
(8) (maximum)	0.54896	0.35542		0.31375	0.35910	0.39760
(9) . (minimum)	0.00001	0.00001		0.00000	0.00000	0.00001
Input / Price						
(10) Primary Metals / El. Machinery	0.24743	0.35542		0.31375	0.35910	0.39760
(11) Fab. Metals / El. Machinery	0.24743	0.35542		0.31375	0.35910	0.39760
(12)						

Table 9: (continued) Representative Elements in Jacobian Matrix

	USA	FRG	ITA	JPN	KOR	TWN
19. Transportation equipment						
(1)Own-diagonals	-0.77198	-0.90280		-0.63171	-0.83487	-0.66067
(2) All-diagonals (average)	-0.95037	-0.96169		-0.93991	-0.95909	-0.94621
(3) (maximum)	-0.67437	-0.78521		-0.63171	-0.79048	-0.66067
(4) (minimum)	-0.99998	-0.99896		-0.99989	-1.00000	-0.99999
(5)Labor	-0.09593	-0.00883		-0.12989	-0.72013	-0.54433
(6)Capital	-0.14068	-0.01253		-0.14390	-0.71544	-0.56434
(7)All off-diagonals (average)	0.03185	0.03831		0.04456	0.03294	0.03159
(8) (maximum)	0.32563	0.21479		0.36829	0.20953	0.33933
(9) (minimum)	0.00001	0.00104		0.00001	0.00000	0.00000
Input / Price						
(10) Primary metals /Trans. Equipment.	0.22802	0.09720		0.36829	0.16514	0.33933
(11) Fab. Metal / El. Machinery	0.22802	0.09720		0.36829	0.16514	0.33933
(12)						
20. Motor vehicles						
(1)Own-diagonals	-0.61369	-0.73913				
(2) All-diagonals (average)	-0.94338	-0.94644				
(3) (maximum)	-0.41793	-0.73252				
(4) (minimum)	-0.99999	-0.99986				
(5)Labor	-0.17098	-0.21146				
(6)Capital	-0.18853	-0.26927				
(7)All off-diagonals (average)	0.02998	0.03188				
(8) (maximum)	0.58208	0.26748				
(9) (minimum)	0.00000	0.00003				
Input / Price						
(10) Primary metals /Motor vehicles	0.38631	0.26087				
(11) Fab. Metals / Motor vehiclues	0.38631	0.26087				
(12)						
21. Precision instrument						
(1)Own-diagonals	-0.93434	-0.85467		-0.73554	-0.62103	
(2) All-diagonals (average)	-0.95276	-0.97475		-0.93246	-0.96274	
(3) (maximum)	-0.75794	-0.83884		-0.68400	-0.62103	
(4) (minimum)	-0.99982	-0.99991		-0.99870	-0.99997	
(5)Labor	-0.05073	-0.31949		-0.19976	-0.83891	
(6)Capital	-0.08316	-0.37442		-0.29561	-0.82900	
(7)All off-diagonals (average)	0.03297	0.02525		0.04336	0.03198	
(8) (maximum)	0.24206	0.16116		0.31600	0.37897	
(9) (minimum)	0.00011	0.00009		0.00024	0.00003	
Input / Price						
(10) Primary Metals / El. Machinery	0.12275	0.06322		0.02730	0.02464	
(11) Fab. Metals / El. Machinery	0.12275	0.06322		0.02730	0.02464	
(12)						

Table 9: (continued) Representative Elements of Jacobian Matrix

	USA	FRG	ITA	JPN	KOR	TWN
22. Miscellaneous manufacturing						
(1) Own-diagonals	-0.89747	-0.88921	-0.77794	-0.78315	-0.88552	-0.87550
(2) All-diagonals (average)	-0.95507	-0.95505	-0.92033	-0.94157	-0.95466	-0.96392
(3) (maximum)	-0.77303	-0.70684	-0.60445	-0.57241	-0.72358	-0.83429
(4) (minimum)	-0.99858	-0.99975	-0.99828	-1.00000	-0.99997	-0.99994
(5) Labor	-0.06569	-0.29466	-0.37626	-0.20680	-0.64598	-0.70069
(6) Capital	-0.08648	-0.38180	-0.41503	-0.32065	-0.68107	-0.76503
(7) All off-diagonals (average)	0.03265	0.02957	0.04373	0.03428	0.03410	0.02731
(8) (maximum)	0.22697	0.29317	0.39555	0.42759	0.27642	0.16571
(9) (minimum)	0.00015	0.00003	0.00065	0.00000	0.00002	0.00005
Input / Price						
(10) Primary Metals / Misc. Mfg.	0.10253	0.11079	0.22206	0.21685	0.11448	0.12450
(11)						
(12)						
23. Total manufacturing						
(1) Own-diagonals	-0.73810	-0.73327	-0.70667	-0.63960	-0.74039	-0.71080
(2) All-diagonals (average)	-0.94872	-0.95584	-0.93245	-0.94077	-0.95738	-0.95930
(3) (maximum)	-0.32292	-0.22092	-0.38911	-0.15233	-0.32989	-0.39612
(4) (minimum)	-1.00000	-0.99997	-0.99976	-1.00000	-1.00000	-1.00000
(5) Labor	-0.22509	-0.26502	-0.39077	-0.27904	-0.71150	-0.58581
(6) Capital	-0.24509	-0.29591	-0.44215	-0.28235	-0.61824	-0.54793
(7) All off-diagonals (average)	0.02999	0.03173	0.04543	0.03784	0.03460	0.03193
(8) (maximum)	0.67708	0.77908	0.61090	0.84768	0.67011	0.60442
(9) (minimum)	0.00000	0.00000	0.00008	0.00000	0.00000	0.00000

In general the own elasticity estimates of labor and capital (rows (5) and (6)) are higher in Asian countries such as Korea and in Taiwan, and in Italy than in Western countries such as the US and Germany, or in Japan. They are highest in Korea and second and third highest in Taiwan and Italy, respectively.[12] They are lowest in the US, and second and third lowest in West Germany and Japan, respectively. It is to be noted, however, that this ordering in elasticity magnitude in absolute values was not as clear in the own and cross price elasticities of material inputs. The economic implications of the magnitude of price elasticity have been discussed in the previous section. Such discussion is valid at the disaggregated level or at the individual industry level.

5. Concluding Remarks

Multi-sectoral production functions are successfully estimated based on the 2-Level

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[12] Such a tendency has already been pointed out in our previous papers (1992a) and (1992b).

CES production function for every industry and country. All production functions satisfied the quasi-concavity condition, and all intermediate inputs as well as labor and capital inputs can be expressed as functions of every commodity price. The estimated parameters are reasonable throughout all the individual industries and countries, showing the substantial stability of our estimation method, which may well serve as a reference for calibration and help to make the empirical implications of the CGE model more realistic.

An international comparison of production structure at the aggregated industry level among six countries indicates that the own price elasticities of the capital, labor, energy, and non-energy materials demand are highest in Korea, second highest in Taiwan, on the high side in Italy, West Germany and Japan, and lowest in the United States. East Asian countries, except for Japan, belong to the high price elasticity group, while Western countries, except for Italy, to the low elasticity one, and the ordering of the magnitude of price elasticity may be determined by the mixed effects of various factors, such as the degree of mechanization of the production process, the degree of modernization of the labor market, the share of production by unincorporated firms in total production, and the diversification of products in large firms.

The elasticity of substitution between capital and energy indicates that it is positive and considerably high in West Germany and Japan, reflecting strong investment activity after the oil crises. The observed tendency that estimates vary widely across both industries and countries may suggest the need for more careful examination of the calibration method in the CGE model based on empirical estimates.

Appendix A: Symbols and Definition of Variables

	Symbol	Definition
(1)	VX_i	Gross output of industry i at market price
(2)	X_i	Gross output of industry i in constant price
(3)	P_i	Price of gross output of industry i
(4)	VX_{ji}	Intermediate input from industry j to industry i at market price
(5)	X_{ji}	Intermediate input from industry j to industry i in constant price
(6)	VE_i	Aggregated energy input of industry i at market price
(7)	E_i	Aggregated energy input of industry i in constant price
(8)	PE_i	Price of E_i
(9)	Vm_i	Aggregated non-energy input of industry i at market price
(10)	M_i	Aggregated non-energy input of industry i in constant price
(11)	PM_i	Price of M_i
(12)	VK_i	Gross capital stock of industry i at market price
(13)	K_i	Gross capital stock of industry i in constant price
(14)	PK_i	Expost rental price of capital stock of industry i
(15)	VL_i	Compensation of employee of industry i at market price
(16)	L_i	Labor input of industry i in constant price
(17)	W_i	Wage rate of industry i
(18)	VEK_i	Aggregated energy-capital input of industry i at market price
(19)	EK_i	Aggregated energy-capital input of industry i in constant price
(20)	PEK_i	Price of EK_i

Appendix B: Weak-separability of Factors of Production

		USA	FRG	ITA	JPN	KOR	TWN
(1)	Food	EM, K, L	EM, K, L	EM, K, L			EM, K, L
(2)	Beverages				EM, K, L		CD^*
(3)	Textile mill products						CD
(4)	Apparels						
(5)	Pulp & paper products					CD^*	
(6)	Printing & publishing	EM, K, L					
(7)	Chemicals	EM, K, L		EM, K, L		CD^*	EM, K, L
(8)	Petroleum & coal products				EM, K, L	CD^*	EM, K, L
(9)	Rubber & plastics	EM, K, L	EM, K, L				
(10)	Leather	EM, K, L					
(11)	Lumber & wood		EM, K, L				
(12)	Furniture						
(13)	Stone, clay, & glass						
(14)	Primary metals		EM, K, L			EM, K, L	CD^*
(15)	Nonferrous metals						
(16)	Fabricated metal products						
(17)	General machinery					CD^{**}	
(18)	Electrical machinery				EM, K, L		CD
(19)	Transportation equipment	EM, K, L	EM, K, L		EM, K, L		
(20)	Motor vehicles						
(21)	Precision instruments	EM, K, L	EM, K, L			CD^*	
(22)	Miscellaneous manufacturing	EM, K, L					

EM, K, L: E and M are weak-separable from other inputs.
CD: Cobb-Douglas production function for $f(K,L,E,M)$.
CD^*: Cobb-Douglas production function for $f(EK, M, L)$.
CD^{**}: Cobb-Douglas production function for $f(EM, K, L)$.
Blank: E and K are weak-separable from other inputs.

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