# Multifactor CES elasticity and productivity growth : a cross-sectional approach

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March 2017

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**Keywords:** Productivity Growth, Multi-Factor CES, Elasticity of Substitution, General Equilibrium, Linked Input-Output Tables

**JEL classification:** D24, D57, D58

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# Multifactor CES Elasticity and Productivity Growth: A Cross-Sectional Approach

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**Abstract**

Sector-wise productivity growth is measured, along with the sectoral elasticity of substitution, under the multifactor CES framework by regressing the growth of factor-wise cost shares against the growth of relative factor prices. We use linked input–output tables for Japan and Korea as the data sources for factor price and cost shares in two temporally distant states. We then construct a multisectoral general equilibrium model using the system of estimated CES unit cost functions and evaluate the economy-wide distribution of exogenous productivity gains in terms of welfare. Further, we examine the differences between models based on a priori elasticities such as the Leontief and the Cobb–Douglas systems.

*Keywords:* Productivity Growth, Multifactor CES, Elasticity of Substitution, General Equilibrium, Linked Input–Output Tables

## 1. Introduction

In this study, we measure productivity growth of multiple industrial sectors, in conjunction with the multifactor constant elasticity of substitution (CES), by way of two temporally distant cross-sectional data sets (i.e., linked input–output tables). As we learn about the multifactor CES unit cost function, we discover that an industry-specific elasticity can be estimated by regressing the growth of factor-wise cost shares against the growth of factor-wise relative prices. We also discover that the industry-specific productivity growth can be measured via the intercept of the regression line. Consequently, we use linked input–output tables to observe the cost shares and relative prices for two periods for multiple industrial sectors.

The two-input CES function was first introduced by Arrow et al. (1961), and Uzawa (1962) and McFadden (1963) later showed that elasticities were still unique for cases with more than two input factors. Subsequent empirical analyses concerning the measurement of CES elasticities (e.g., van der Werf, 2008; Koesler and Schymura, 2015) have been undertaken to handle elasticities between more than two factors of production by way of time-series observations while embedding nest structures into the two-input CES framework that conforms to the work by Sato (1967). The number of factors and, thus, estimable elasticities can nevertheless be narrowed depending on the availability of time-series data. Since we are interested in constructing a multisector general equilibrium model that calls for multifactor production functions, we can take advantage of an alternative approach.

When a multisectoral general equilibrium model is established, assessments can be made, in terms of welfare, of the arbitrary productivity shock that results from technological innovation. Previous studies on this topic have assumed a constant and unanimous unit elasticity (Klein, 1952–1953) or have used empirically estimated elasticities in translog or multistage (nested) CES functions with a highly aggregated and, thus, limited number of substitutable factors. Examples include works by Kuroda et al. (1984), Saito and Tokutsu (1989), and Tokutsu (1994), and a significant amount of work concerning CGE models, such as Böhringer et al. (2015). In contrast, our approach allows us to construct an empirical model of multifactor production with different elasticities of substitution among many (over 350) industrial sectors. Moreover, our approach allows us to prospectively portray the ex post technological structure following any given exogenous productivity shocks and to account for welfare in terms of economy-wide input–output performances.

The remainder of this paper is organized as follows. In the Section 2, we introduce the basics of the multifactor CES elasticity and productivity growth estimation and apply the protocol to linked input-output tables for Japan and Korea that have sufficient capacity as far as the degrees of freedom of the regressions are concerned. In Section 3, we replicate the current technological structure as the general equilibrium state of a system of empirically estimated multifactor CES functions; further, we trace how that structure is transformed by exogenous productivity stimuli. Section 4 provides concluding remarks.

## 2. The Model

### *2.1. Multifactor CES Functions*

A constant-return multifactor CES production function of an industrial sector (index $j$ omitted) has the following form:

$$y = \theta f\left(\mathbf{x}\right) = \theta \left( \sum_{i=0}^{n} \delta_i^{\frac{1}{\sigma}} x_i^{\frac{\sigma-1}{\sigma}} \right)^{\frac{\sigma}{\sigma-1}}$$

where $y$ is the output and $x_i$ is the $i$th factor input. Here, the share parameters are assumed to maintain $\delta_i > 0$ and $\sum_i \delta_i = 1$, while the elasticity of substitution $\sigma \geq 0$ is subject to estimation. Also, we are interested in measuring the growth of productivity, i.e., $\Delta \ln z$, where $\Delta$ represents temporally distant differences.

The expression below shows the unit cost function compatible with the multifactor CES production function:

$$c = \theta^{-1} h\left(\boldsymbol{w}\right) = \frac{1}{\theta} \left( \sum_{i=0}^{n} \delta_i w_i^{\rho} \right)^{\frac{1}{\rho}}$$

where $c$ denotes the unit cost of the output and $w_i$ denotes the $i$th factor price. Here, we use $\rho = 1 - \sigma$ for convenience. The cost share of the $i$th input, $a_i$, can be determined, with regard to

Shephards lemma, by differentiating the unit cost function:

$$a_i = \frac{\partial c}{\partial w_i}\frac{w_i}{c} = \delta_i \left(\theta c / w_i\right)^{-\rho} \tag{1}$$

By taking the log of both the sides, we have

$$\ln a_i = \ln \delta_i - \rho \ln \theta + \rho \ln \left(w_i / c\right)$$

We observe two temporally distant values for cost shares ($a_i^0$ and $a_i^1$), factor prices ($w_i^0$ and $w_i^1$), and unit costs of outputs as prices ($c^0 = w^0$ and $c^1 = w^1$) reflecting perfect competition, and, we find two identities regarding the data:

$$\begin{aligned} \ln a_i^0 &= \ln \delta_i - \rho \ln \theta^0 + \rho \ln \left(w_i^0 / w^0\right) + \epsilon_i^0 \\ \ln a_i^1 &= \ln \delta_i - \rho \ln \theta^1 + \rho \ln \left(w_i^1 / w^1\right) + \epsilon_i^1 \end{aligned}$$

where we assume that $\epsilon_i^0$ and $\epsilon_i^1$ are identically and normally distributed disturbance terms. Subtraction results in the main regression equation as follows:

$$\Delta \ln a_i = -\rho \Delta \ln \theta + \rho \Delta \ln \left(w_i / w\right) + \epsilon_i \tag{2}$$

Here, the disturbance term $\epsilon_i = \epsilon_i^0 - \epsilon_i^1$ is identically and normally distributed so that one can estimate $\rho$ and $\Delta \ln \theta$ via the simple linear regression shown in equation (2). That is, by regressing the growth of factor-wise cost shares (i.e, $\Delta \ln a_i$) on the growth of relative prices (i.e., $\Delta \ln \left(w_i / w\right)$), the slope obtained gives the estimate of $\rho$ and the intercept gives the estimate of $-\rho \Delta \ln \theta$. Also, note that $\delta_i$ can be calibrated via equation (1) as long as we have the estimate for $\rho$.

### *2.2. The Data and Estimations*

A set of linked input–output tables includes sectoral transactions in both nominal and real terms. Since real value is adjusted for inflation in order to enable a comparison of quantities as if the prices had not changed, and since the nominal value is not adjusted, we use a price index to convert nominal into real values. That is, if we standardize the value of a commodity at the reference state as real, its nominal (unadjusted) value at the target state relative to the reference state equals the price index called a deflator. Naturally, the 1995–2000–2005 linked input–output tables for both Japan (MIAC, 2011) and Korea (BOK, 2015) include factor-wise deflators (395 factors for Japan and 350 factors for Korea) spanning the fiscal years recorded. These linked input–output tables, however, do not include deflators for primary factors (i.e., labor and capital); and therefore, we used the quality-adjusted price indexes compiled by the JIP (2015) for Japan and by the KIP (2015) for Korea in order to inflate the nominal values of primary inputs.

Hence, observations for both the dependent variable (cost shares as input–output coefficients $a_{ij}$) and the independent variable (price ratios $w_j / w_i$) for estimating equation (2) become available with sufficient capacity in terms of degrees of freedom as we verify that there are $n + 1$ inputs, namely, $i = 0, 1, \cdots, n$ and $n$ outputs, namely, $j = 1, \cdots, n$, for an input–output table. In particular, we use the 2000 and 2005 input–output coefficient matrices from the three-period linked input–output tables as the data for the cost share growth (i.e., $\Delta \ln a_{ij}$). As we set the reference state at year 2000, the five-year growth of output-relative factor prices simply becomes the log difference between deflators:

$$\Delta \ln w_i / w_j = \ln p_i / p_j$$

where $p_i$ denotes the deflator for commodity $i$ in year 2005 with respect to year 2000.

Figure 1 displays the estimated CES elasticity (i.e., $\sigma_j = 1 - \rho_j$ for all $j$) with respect to the statistical significance of $\rho_j$, i.e., the slope of the regression in equation (2) in terms of standard error, for Japan. Figure 2 displays the same for Korea. Note that the CES elasticities are statistically significant (p-value $< 0.1$) for 176 out of 395 sectors for Japan and 166 out of 350 sectors for Korea. The estimation results are summarized in Tables 3 and 4 for Japan and Korea, respectively. These tables include sectors whose slopes ($\rho_j = 1 - \sigma_j$) of the regression equation (2) are statistically significant; and we indicate the level of significance by *** (0.01 level), **(0.05 level), and *(0.1 level), along with the estimated elasticities. In the third column of Tables 3 and 4, we display the productivity growth, $\Delta \ln \theta$, labeled as TFPg (Total Factor Productivity growth). These numbers are the estimated constant terms of equation (2) divided by the negative of the corresponding slope that is estimated at the same time. Here, the indicated statistical significances are the constant terms of equation (2). Also, note that these tables are sorted by the level of estimated TFPg.

Let us now assess the estimated TFPg with regard to other possible productivity measurements. Below is the log of the Törnqvist index, the exactness of which Diewert (1976) demonstrated by measuring the productivity growth of translog functions. Thus, we know that equation (3) is equal to the productivity growth of the underlying translog function, with or without knowing its parameters.

$$\text{TFPg (translog)} = -\ln p + \sum_{i=0}^{n} \left( \frac{a_i^0 + a_i^1}{2} \right) \ln p_i \tag{3}$$

Note that although it is almost impossible to estimate the parameters of a translog function with one hundred factor inputs, its productivity growth can be measured using the same data (cost shares and price changes) as those used in estimating the productivity for a multifactor CES function.

In Figures 3 and 4, we plot the estimated TFP as index numbers, i.e., $\theta_j^1 / \theta_j^0$, for a multifactor CES function, tagged as TFP (CES), for all sectors listed in Tables 3 and 4 against the log of the Törnqvist indexes, tagged as TFP (translog). Blue dots indicate sectors whose slope and regression constant for equation (2) are both statistically significant (p-value $< 0.1$), whereas red dots indicate sectors whose slope is significant but constant is not. In both cases, we observe correlations between the two TFP measurements; therefore, we evaluate them objectively, as summarized in Table 1. Here, "Correlation" designates Pearson's correlation coefficient, whereas "Concordance" designates Lin's concordance correlation coefficient (Lin, 2000). In other words, by way of a multifactor CES function, we obtain TFP estimates similar to those based on translog functions that are very general in terms of their elasticities of substitution, set aside their estimability; yet, a multifactoral elasticity of substitution can be estimated for many factor inputs. Note, however, that the null hypothesis has to be accepted (i.e., $\rho_j = 1 - \sigma_j = 0$) for sectors where the slope of the

Table 1: Concordances and correlations between Translog and multifactor CES TFP gain estimates.

| Dots | Concordance | Correlation | Obs. |
|---|---|---|---|
| Red & Blue (JPN) | 0.655 | 0.669 | 176 |
| Red (JPN) | 0.625 | 0.759 | 100 |
| Blue (JPN) | 0.668 | 0.816 | 76 |
| Red & Blue (KOR) | 0.356 | 0.419 | 166 |
| Red (KOR) | 0.312 | 0.333 | 97 |
| Blue (KOR) | 0.276 | 0.405 | 69 |

regression (2) is not statistically significant and, in that event, we assume that the function follows Cobb–Douglas and that TFP is unmeasurable.

## 3. Prospective Analysis

### *3.1. Projected Prices*

In this section, we construct a multisectoral general equilibrium model that reflects all measured elasticities and observed current cost shares; further, we exogenously impose some productivity change onto the model and simulate the multisectoral distribution that can potentially take place. For the sake of simplicity, let us normalize all current prices at unity. In that event, we recall equation (1):

$$a_{ij} = \delta_{ij}, \qquad \sum_{i=0}^{n} a_{ij} = 1, \quad j = 1, 2, \cdots, n$$

Then, the system of CES unit cost functions in equilibrium, under some exogenously given productivity change; i.e., $\boldsymbol{\theta} = (\theta_1, \theta_2, \cdots, \theta_n) \neq \mathbf{1}$, must be in the following state:

$$\begin{aligned} \pi_1 &= \theta_1^{-1} \left( a_{01}\pi_0^{\rho_1} + a_{11}\pi_1^{\rho_1} + \cdots a_{n1}\pi_n^{\rho_1} \right)^{\frac{1}{\rho_1}} \\ \pi_2 &= \theta_2^{-1} \left( a_{02}\pi_0^{\rho_2} + a_{12}\pi_1^{\rho_2} + \cdots a_{n2}\pi_n^{\rho_2} \right)^{\frac{1}{\rho_2}} \\ &\vdots \\ \pi_n &= \theta_n^{-1} \left( a_{0n}\pi_0^{\rho_n} + a_{1n}\pi_1^{\rho_n} + \cdots a_{nn}\pi_n^{\rho_n} \right)^{\frac{1}{\rho_n}} \end{aligned} \tag{4}$$

where the projected (ex post) general equilibrium price for factor $i$ is denoted by $\pi_i$. Note that the current state (i.e., $\boldsymbol{\theta} = \mathbf{1}$) can be reproduced by setting all prices at the current state (i.e., $\boldsymbol{\pi} = \mathbf{1}$) and vice versa.[1]

The projected price after the exogenous productivity change can be obtained by solving equation

[1]This may not be so obvious when $\boldsymbol{\rho} = \mathbf{0}$, until we see (7).

(4) for $\boldsymbol{\pi}$. By rearranging, we obtain the following:

$$\begin{aligned} \theta_1^{\rho_1}\pi_1^{\rho_1} &= a_{01}\pi_0^{\rho_1} + a_{11}\pi_1^{\rho_1} + \cdots a_{n1}\pi_n^{\rho_1} \\ \theta_2^{\rho_2}\pi_2^{\rho_2} &= a_{02}\pi_0^{\rho_2} + a_{12}\pi_1^{\rho_2} + \cdots a_{n2}\pi_n^{\rho_2} \\ &\vdots \\ \theta_n^{\rho_n}\pi_n^{\rho_n} &= a_{0n}\pi_0^{\rho_n} + a_{1n}\pi_1^{\rho_n} + \cdots a_{nn}\pi_n^{\rho_n} \end{aligned}$$

or by way of row vectors and matrices:

$$\boldsymbol{\pi}^{\boldsymbol{\rho}} \langle \boldsymbol{\theta}^{\boldsymbol{\rho}} \rangle = \mathbf{a}_0 + \boldsymbol{\pi}^{\boldsymbol{\rho}} \mathbf{A}$$

where $\boldsymbol{\pi}^{\boldsymbol{\rho}} = \left(\pi_1^{\rho_1}, \cdots, \pi_n^{\rho_n}\right)$ and $\boldsymbol{\theta}^{\boldsymbol{\rho}} = \left(\theta_1^{\rho_1}, \cdots, \theta_n^{\rho_n}\right)$, while we set the price of a primary input as a numéraire (i.e., $\pi_0 = 1$). Angle brackets indicate diagonalization. Note that $\mathbf{A}$ and $\mathbf{a}_0$ are the current input–output coefficients matrix and the value added coefficients vector, respectively. Now, the projected equilibrium price $\boldsymbol{\pi}$ can be obtained:

$$\boldsymbol{\pi} = \left(\mathbf{a}_0 \left[\langle \boldsymbol{\theta}^{\boldsymbol{\rho}} \rangle - \mathbf{A}\right]^{-1}\right)^{\frac{1}{\rho}} \tag{5}$$

Besides CES, we may use equation (5) to obtain the projected price for the cases of Leontief ($\boldsymbol{\rho} = \mathbf{1}$) and Cobb–Douglas ($\boldsymbol{\rho} = \mathbf{0}$) cases. The Leontief case is straightforward:

$$\boldsymbol{\pi} = \mathbf{a}_0 \left[\langle \boldsymbol{\theta} \rangle - \mathbf{A}\right]^{-1} \tag{6}$$

For the Cobb–Douglas case, we first take the log of equation (4) and then let $\boldsymbol{\rho} \to \mathbf{0}$. As shown below, we determine the unit cost function of any industrial sector $j$ while omitting the subscript:

$$\ln \pi + \ln \theta = \frac{\ln\left(a_0 + \sum_{i=1}^n a_i \pi_i^{\rho}\right)}{\rho} \to \sum_{i=1}^n a_i \ln \pi_i$$

Here, we applied l'Hospital's rule when we let $\rho \to 0$ since, in that event the numerator and denominator both approach zero. By way of row vectors and matrices, this can be written concisely in the following manner:

$$\ln \boldsymbol{\pi} = -\ln \boldsymbol{\theta} + (\ln \boldsymbol{\pi}) \mathbf{A} \tag{7}$$

where the log operators are applied by element. The Cobb–Douglas version of the projected price will thus be expressed as follows:

$$\boldsymbol{\pi} = \exp\left(-(\ln \boldsymbol{\theta}) \left[\mathbf{I} - \mathbf{A}\right]^{-1}\right) \tag{8}$$

*3.2. Projected Structures*

Since we set the current price to unity, the final demand in monetary terms will be the same as the physical quantity demanded. Let the current (nominal) final demand be denoted by a column vector $\mathbf{d} = (d_1, \cdots, d_n)^\intercal \geq \mathbf{0}$. Note that the sum of product-wise final demand and that of sector-wise value added (the social cost) equals the GDP. If we have the projected price is attributable to some exogenous productivity change, we can evaluate the corresponding welfare change in terms of the social cost saved (SCS, hereafter); that is,

$$\text{SCS} = \sum_{j=1}^{n} v_j - v'_j = (\mathbf{1} - \boldsymbol{\pi})\,\mathbf{d} \tag{9}$$

The sector-wise distribution of the SCS, however, requires more examination of the projected structure of the economy.

According to equation (1), the projected cost shares, which we denote $b_{ij}$, the ex post the exogenous productivity change $z_j$ for sector $j$, can be evaluated using the following:

$$b_{ij} = a_{ij}\left(\theta_j \pi_j / \pi_i\right)^{-\rho_j} \qquad i = 0, 1, \cdots, n \tag{10}$$

Hence, under CES, the projected primary factor input (or value added) distribution $\mathbf{v}' = \left(v'_1, \cdots, v'_n\right)$ including all sectors for a given fixed final demand $\mathbf{d}$ (in physical quantity), can be evaluated as follows:

$$\mathbf{v}' = \mathbf{b}_0 \left\langle [\mathbf{I} - \mathbf{B}]^{-1} \langle \boldsymbol{\pi} \rangle\, \mathbf{d} \right\rangle \tag{11}$$

where the entries for $\mathbf{b}_0$ and $\mathbf{B}$ are specified by equation (10). Conversely, the current distribution of primary factor inputs (or value added) $\mathbf{v} = (v_1, \cdots, v_n)$ is specified by the current observed cost shares as follows:

$$\mathbf{v} = \mathbf{a}_0 \left\langle [\mathbf{I} - \mathbf{A}]^{-1}\, \mathbf{d} \right\rangle \tag{12}$$

Since equations (11) and (12) are row vectors, one can evaluate the SCS in terms of sector-wise distribution.

Let us now consider the Cobb–Douglas case. By taking the log of equation (10) and then letting $\rho_j \to 0$ for all $j$, we obtain the following:

$$\ln b_{ij} = \ln a_{ij} - \rho_j \ln\left(\theta_j \pi_j / \pi_i\right) \to \ln a_{ij}$$

Thus, the projected primary factor inputs distribution for the Cobb–Douglas case is as follows:

$$\mathbf{v}' = \mathbf{a}_0 \left\langle [\mathbf{I} - \mathbf{A}]^{-1} \langle \boldsymbol{\pi} \rangle\, \mathbf{d} \right\rangle \tag{13}$$

As for the Leontief case, by plugging equation (10), with $\rho_j = 1$ for all sector $j$ into equation (11), we obtain the following formula:

$$\begin{aligned} \mathbf{v}' &= \mathbf{a}_0 \langle \boldsymbol{\pi} \rangle^{-1} \langle \boldsymbol{\theta} \rangle^{-1} \left\langle \left[\mathbf{I} - \langle \boldsymbol{\pi} \rangle\, \mathbf{A} \langle \boldsymbol{\pi} \rangle^{-1} \langle \boldsymbol{\theta} \rangle^{-1}\right]^{-1} \langle \boldsymbol{\pi} \rangle\, \mathbf{d} \right\rangle \\ &= \mathbf{a}_0 \left[\langle \boldsymbol{\theta} \rangle - \mathbf{A}\right]^{-1} \langle \mathbf{d} \rangle \end{aligned} \tag{14}$$

Finally, one can verify that when $\mathbf{A} \geq \mathbf{0}$ and $\boldsymbol{\theta} > \mathbf{0}$, the following must be true:

$$
\begin{aligned}
[\langle \boldsymbol{\theta} \rangle - \mathbf{A}]^{-1} &= \langle \boldsymbol{\theta} \rangle^{-1} + \mathbf{A} \langle \boldsymbol{\theta} \rangle^{-2} + \mathbf{A}^2 \langle \boldsymbol{\theta} \rangle^{-3} + \cdots > \mathbf{0} \\
[\mathbf{I} - \mathbf{A}]^{-1} &= \mathbf{I} + \mathbf{A} + \mathbf{A}^2 + \cdots > \mathbf{I}
\end{aligned}
\tag{15}
$$

Thus, we see that

$$
\begin{aligned}
[\langle \boldsymbol{\theta} \rangle - \mathbf{A}]^{-1} &\leq [\mathbf{I} - \mathbf{A}]^{-1} && \text{if } \boldsymbol{\theta} \geq \mathbf{1} \\
[\langle \boldsymbol{\theta} \rangle - \mathbf{A}]^{-1} &\geq [\mathbf{I} - \mathbf{A}]^{-1} && \text{if } \mathbf{0} < \boldsymbol{\theta} \leq \mathbf{1}
\end{aligned}
$$

Hence, according to euqations (12) and (14), we find that $\mathbf{v} - \mathbf{v}' \geq \mathbf{0}$, if $\boldsymbol{\theta} \geq \mathbf{1}$, and $\mathbf{v} - \mathbf{v}' \leq \mathbf{0}$, if $\mathbf{0} < \boldsymbol{\theta} \leq \mathbf{1}$, for the Leontief system. Moreover, because $[\mathbf{I} - \mathbf{A}]^{-1} > \mathbf{I}$, we find that $\boldsymbol{\pi} \leq \mathbf{1}$ if $\boldsymbol{\theta} \geq \mathbf{1}$ and $\boldsymbol{\pi} \geq \mathbf{1}$ if $\mathbf{0} < \boldsymbol{\theta} \leq \mathbf{1}$ by equation (8) for the Cobb–Douglas system. Hence, from equations (12) and (13), we find that $\mathbf{v} - \mathbf{v}' \geq \mathbf{0}$, if $\boldsymbol{\theta} \geq \mathbf{1}$, and $\mathbf{v} - \mathbf{v}' \leq \mathbf{0}$, if $\mathbf{0} < \boldsymbol{\theta} \leq \mathbf{1}$ for the Cobb–Douglas system as well.

To summarize, the following must be true for both the Leontief and Cobb–Douglas systems:

$$
\begin{aligned}
\mathbf{v} - \mathbf{v}' &\geq \mathbf{0} && \text{if } \boldsymbol{\theta} \geq \mathbf{1} \\
\mathbf{v} - \mathbf{v}' &\leq \mathbf{0} && \text{if } \mathbf{0} < \boldsymbol{\theta} \leq \mathbf{1}
\end{aligned}
\tag{16}
$$

In other words, the SCS will be positive for all sectors if the exogenous productivity change is increasing, and negative for all sectors if the exogenous productivity change is decreasing. THis is applicable to systems with unanimous elasticity, such as Leontief and Cobb–Douglas. In contrast, we find nothing definitive about the CES system, in general.

*3.3. Simulations*

Let us now apply the framework discussed in the previous sections. First, we calibrate the multisectoral models with different elasticities, namely the Leontief, the Cobb–Douglas, and the multifactor CES models, as of 2005. Thus, the cost shares of the current state (i.e., $\mathbf{a}_0$ and $\mathbf{A}$) are as of 2005. For the multifactor CES system, we make use of the elasticities that are statistically significant, i.e., the sectors displayed in Tables 3 and 4; we assume unit elasticity (or the null hypothesis) for the remainder of the sectors.

As for the exogenous productivity change ($\boldsymbol{\theta}$), we examine the productivity doubling of the Ready Mixed Concrete sector (RMC, hereafter), which is 150th sector in Japan, and the 159th in Korea. Thus,

$$
\begin{aligned}
\text{Japan:} \quad & z_{j=150} = 2, \quad z_{j \neq 150} = 1 \quad (n = 395) \\
\text{Korea:} \quad & z_{j=159} = 2, \quad z_{j \neq 159} = 1 \quad (n = 350)
\end{aligned}
\tag{17}
$$

There are a couple of reasons for choosing this sector. One reason is its stimulus is more influential than not throughout the economy. In other words, upstream industrial sectors are preferable because they are able to influence all downstream sectors, whereas downstream sectors hardly have any influence on upstream sectors. Based on the work by Chenery and Watanabe (1958), we performed triangulation[2] on the 2005 input–output coefficient matrices for both Japan and Korea. We found that the RMC sector was placed in the upper stream of the supply chain in both economies (137th out of 395 for Japan, and 65th out of 350 for Korea). Another criterion for selecting is that the output of the sector be completely domestic (not imported) as the current study precludes international trade. Most importantly, we required the equivalence of the sector to be examined for both countries. The RMC sector meets all of these criteria.

In Table 2, we summarize the results of our SCS calculations via equation (9) for the three systems, namely, Leontief, Cobb–Douglas, and CES in Japan and Korea. The projected equilibrium price $\boldsymbol{\pi}$ for given $\boldsymbol{\theta}$ as in equation (17), is calculated using equation (6) for the Leontief system, equation (8) for the Cobb–Douglas system, and equation (5) for the CES system. Along with the SCS, we Show the output of the RMC sector of the 2005 input–output table. Notably, the SCS of

Table 2: SCS (social cost saved) by productivity doubling of RMC (ready mixed concrete) sector. Values in parentheses are the kurtosis of the SCS distribution.

| | Japan [BJPY] | | Korea [BKRW] | |
|---|---|---|---|---|
| Output | 1,347 | | 6,398 | |
| SCS Leontief | 674 | (315) | 3,203 | (162) |
| SCS Cobb–Douglas | 926 | (52) | 4,349 | (84) |
| SCS CES | 944 | (45) | 4,550 | (102) |

the Leontief system is very slightly larger than one-half the output of the RMC sector, reflecting the double productivity of the RMC sector. Regarding equation (15), this is legitimate as we consider the following:

$$[\mathbf{I} - \mathbf{A}]^{-1} - [\langle \boldsymbol{\theta} \rangle - \mathbf{A}]^{-1} \approx \mathbf{I} - \langle \boldsymbol{\theta} \rangle^{-1} = 1/2$$

Conversely, the SCS of the Cobb–Douglas and CES systems is larger than that of the Leontief system, reflecting further transmissions across sectors that have greater elasticity. Note that the average of all elasticities i.e., $\sum_{j=1}^{n} \sigma_j / n$ of the CES system was 1.32 for Japan and 1.39 for Korea.

Let us now look at the sectoral distribution of the SCS. Figures 5, 6, and 7 show the projected sector-wise SCS from productivity doubling of the RMC sector in Japan under the Leontief, Cobb–Douglas, and CES systems, respectively. Corresponding figures for Korea are shown in Figures 8, 9, and 10. As anticipated with regard to equation (16), the SCS for the Leontief and Cobb–Douglas systems is positively distributed overall.[3]

Basically, when there is productivity doubling in one sector, its price will be cut in half. The intersectoral propagation of that price change will nevertheless be different, depending on the elasticity of factor substitution among the interacting sectors. As for the Leontief system, because factor substitution will not exist with any other sector, the price change of RMC to half its former level will have no effect upon its intermediate demand. Thus, in this case, all the factor inputs

[2]Stages of production leading to final goods are investigated through permutation of sectors. See, e.g., Chaovalitwongse et al. (2011) for recent methodological progress.

[3]However, due to the negative entries for $\mathbf{d}$, slightly negative values are observed.

(including the primary factor) for the RMC sector will be reduced by half. This is the main reason why the primary factor for the RMC sector (as SCS) is reduced rather significantly for the Leontief system. Consequently, the intermediate demand for the factors (including the primary factor) will be respectively reduced by as much as half the amount that used to go into the RMC sector. Such a reduction in intermediate demand and thus, supply, will accumulated with convergence. In other words, at least half of the primary factor will be directly reduced in the RMC sector and indirectly reduced in any other sector. Figures 5 and 8 reflect the results of productivity doubling in the RMC sector on the primary factor demand under a system of zero elasticity of substitution.

In contrast, for the Cobb–Douglas system, the intermediate demand for RMC, when its price is reduced to half, must double, which is the very definition of the unit elasticity of substitution. Thus, in this case, the monetary output and factor inputs (including the primary factor) of the RMC sector will not change. As for an elastic CES system, where the elasticity of substitution is greater than unity, the factor demand for RMC increases by more than double when the price of RMC is reduced by half. And in this case, the factor inputs of the RMC sector can be increased.[4] Since the unit cost functions are strictly concave in both systems, the price of all factors except that of the primary factor, which will stay constant, will converge in a strictly descending manner. Hence, in equilibrium, the primary factor will be reduced for the sectors where the primary factor becomes relatively more expensive as compared with the other factor inputs.

Notably, Figures 6 and 7 indicate that the primary factor is reduced rather prominently (as SCS) for some sectors in Japan, namely, Public construction of roads (279th), Public construction of rivers, drainages, and others (280th), and Residential construction (non-wooden) (275th). Figures 9 and 10 indicate that Residential building construction (289th), Road construction (272nd), and Non-residential building construction (270th) are the prominent sectors where the primary factor is reduced rather prominently (as SCS) for Korea. These sectors obviously utilize RMC extensively for production. In other words, the primary factor in these sectors will be substituted by RMC because of its reduced price.

Moreover, these figures show that not only is the magnitude of propagation (in terms of SCS) of the productivity stimuli magnified by larger elasticities of substitution but the distribution of the SCS becomes more even. We measured the polarity of the distribution of SCS among the sectors via kurtosis, as displayed in the parentheses in Table 2. The primary factor is largely reduced in the RMC sector, where the productivity is enhanced for the Leontief system, whereas the reduction of the primary factor is spread among the sectors for the Cobb–Douglas and CES systems. Put differently, the welfare gain of enhanced productivity in one industry is mainly attained as the curtailment of factor inputs of that particular industry while keeping the output level constant in the Leontief system. In contrast, in the Cobb–Douglas and CES systems, the reduced price is appreciated by other industries, so their primary factors are reduced by substitution.

## 4. Concluding Remarks

To date, input–output analysis has been a one-of-a-kind framework that considers industrywide impacts when assessing the costs and benefits of new goods and innovations. Nonetheless, input–

[4]This is the main reason why we observe, in Figures 7 and 10, negative SCS (increased primary factor input) in the RMC sector.

output theory has also been used to analyze the non-substitution theorem, which allows researchers to apply a fixed technological structure while restricting the subject of analysis to transformations within final demand. Substitution of technology will always take place in any industry when new technology is introduced into any component (industry and sector) of the economy. Larger influences are typically foreseeable for intermediate industries, as they have much greater and wider feedback on economy-wide systems of production.

In order to consider all technology substitution possibilities, we have proposed a methodology to measure the sector-wise elasticity of substitution for the CES production function, rather than using uniform a priori elasticities of substitution (such as zeros and ones) when modeling economy-wide, multisector, and multifactor production systems. A dual analytical method (i.e., unit cost functions) was used to evaluate the influences on general equilibrium technological substitutions and, eventually, on the social costs and benefits initiated by the introduction of innovations, which we treat as gains in productivity. We have found that the more elastic production functions (Cobb–Douglas and CES) have more significant and wider transmission effects, whereas inelastic production functions (Leontief) have relatively less effects that are polarized. Applications and extensions of this framework could be substantial, including international, dynamic, and quality considerations that remain open for future investigations.

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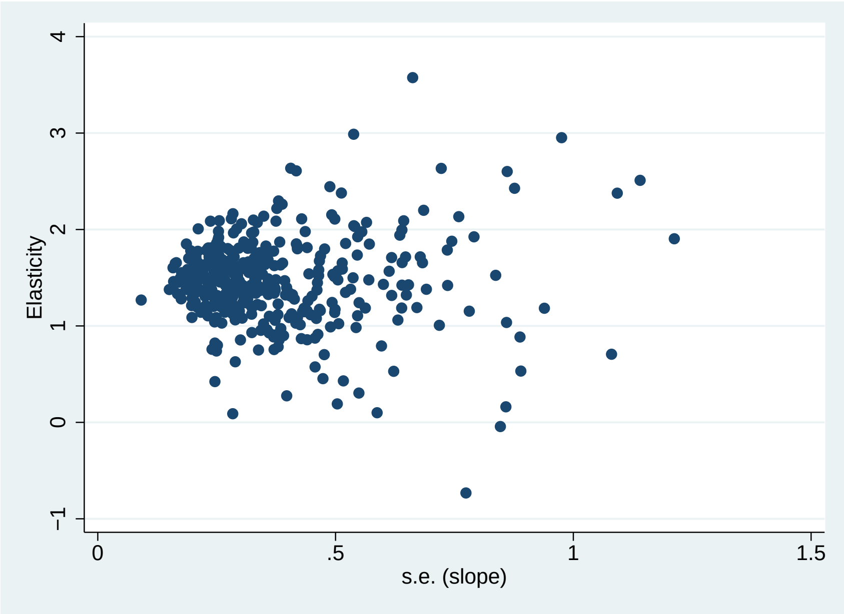


Figure 1: CES elasticity vs significance (Japan)

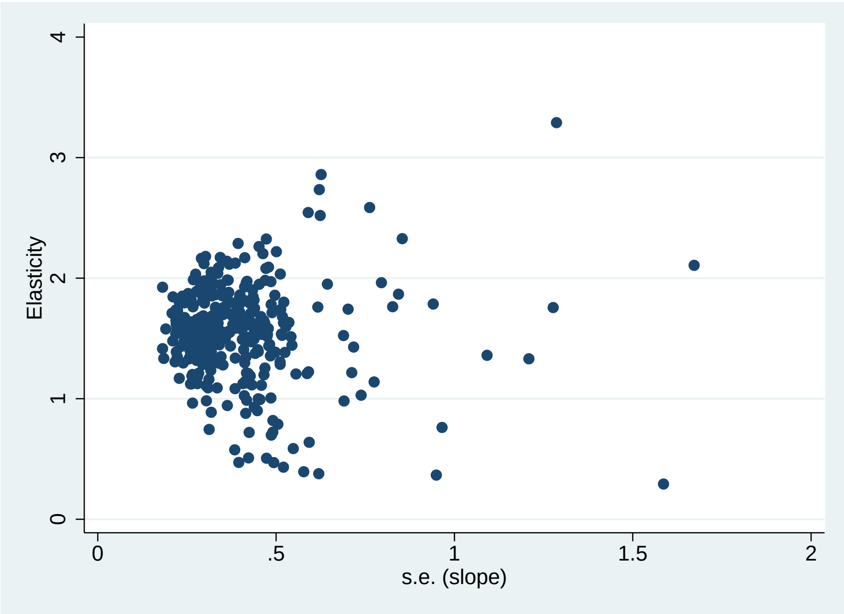


Figure 2: CES elasticity vs significance (Korea)

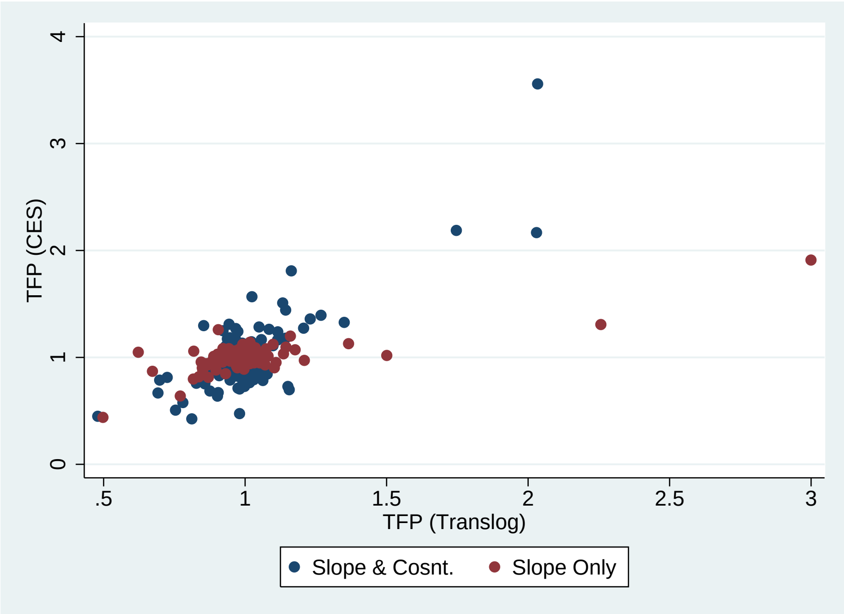


Figure 3: TFP (index) of different measurements. (Japan)

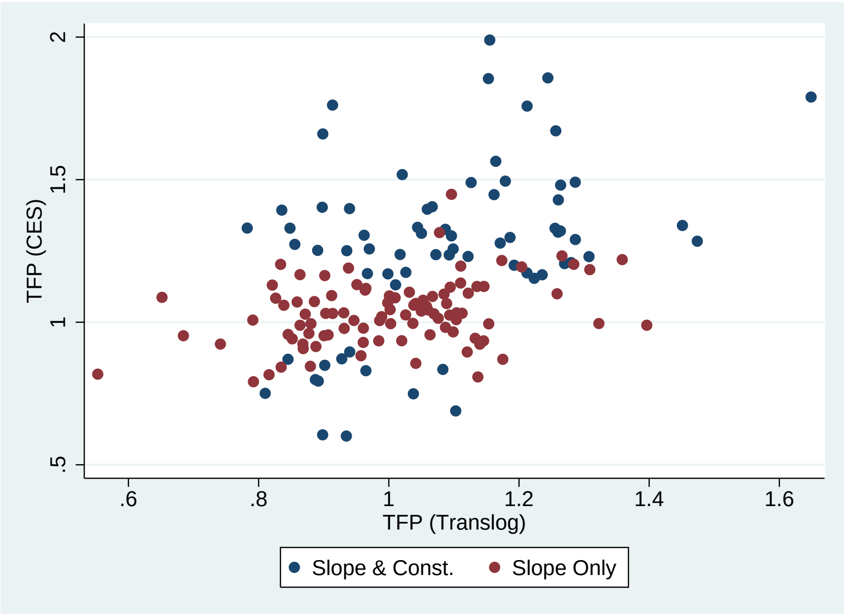


Figure 4: TFP (index) of different measurements. (Korea)

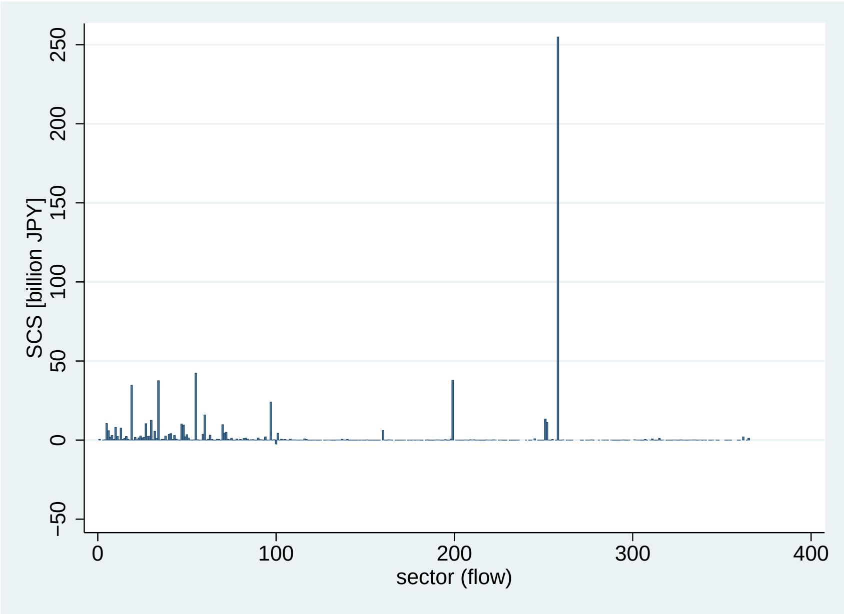


Figure 5: Sectoral distribution of SCS for productivity doubling of the RMC sector (150th) for Leontief system. (Japan)

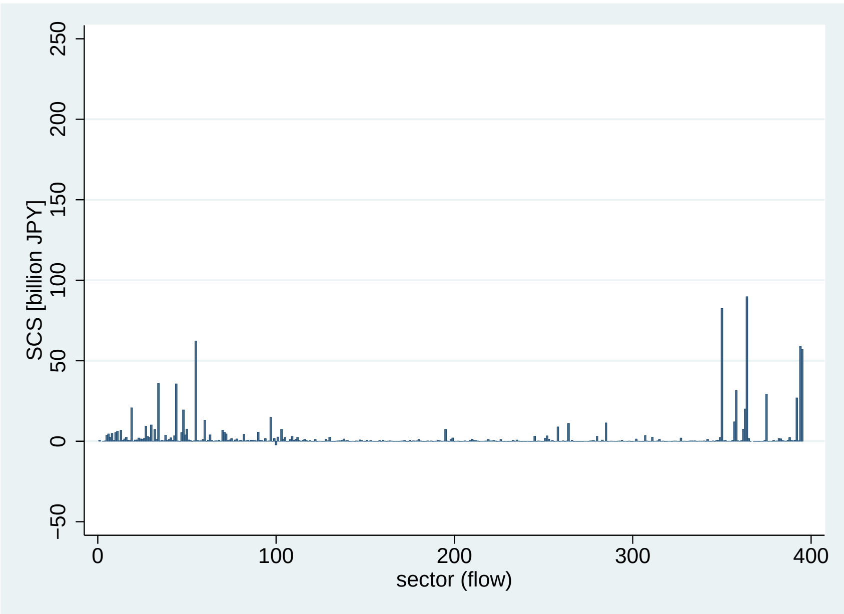


Figure 6: Sectoral distribution of SCS for productivity doubling of RMC sector (150th) for Cobb–Douglas system. (Japan)

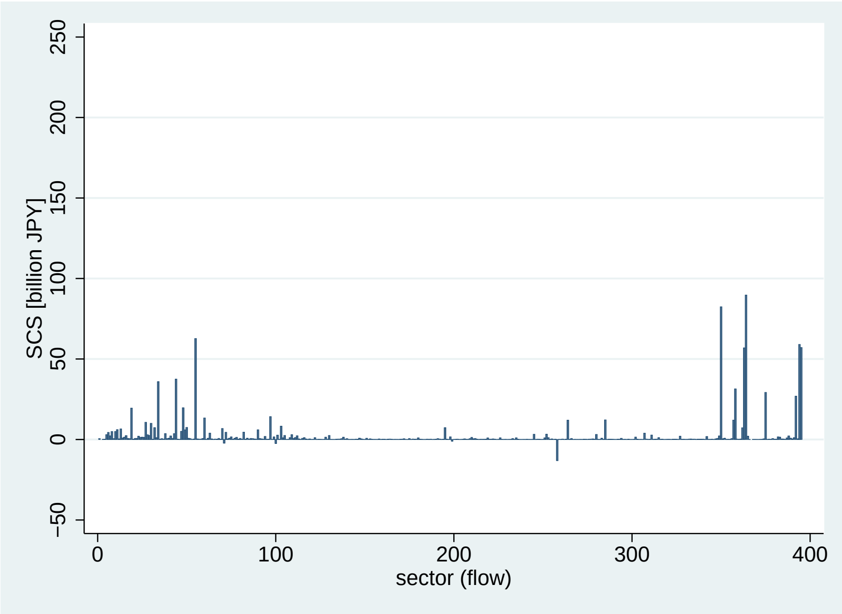


Figure 7: Sectoral distribution of SCS for productivity doubling of RMC sector (150th) for multifactor CES system. (Japan)

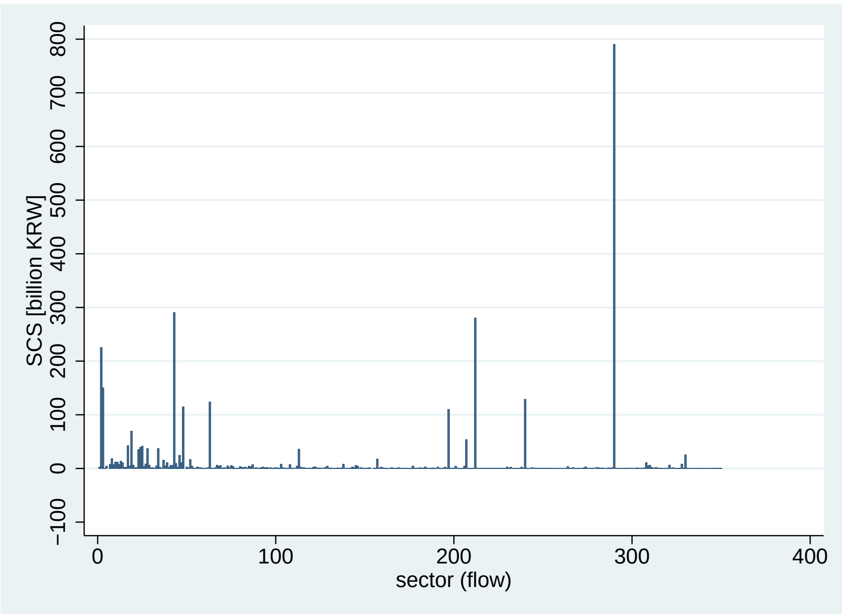


Figure 8: Sectoral distribution of SCS for productivity doubling of RMC sector (159th) for Leontief system. (Korea)

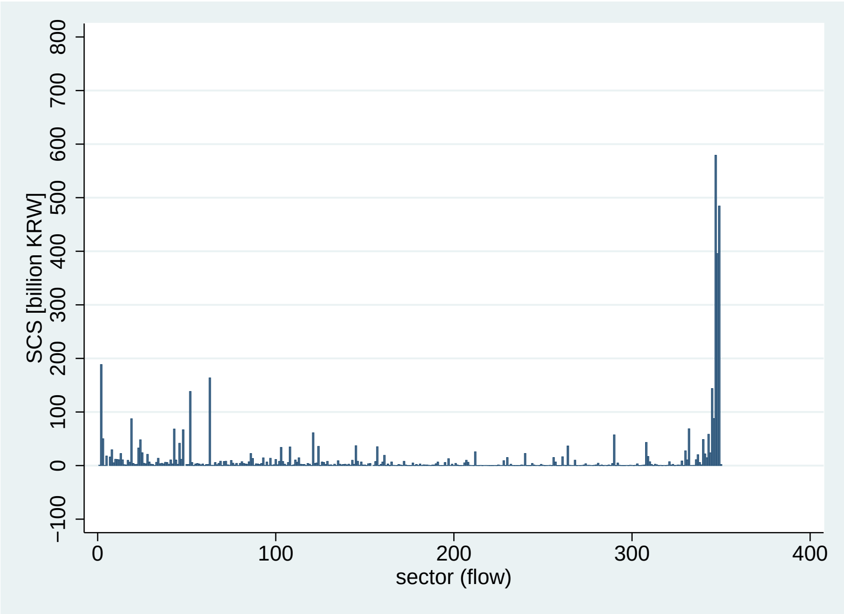


Figure 9: Sectoral distribution of SCS for productivity doubling of RMC sector (159th) for Cobb–Douglas system. (Korea)

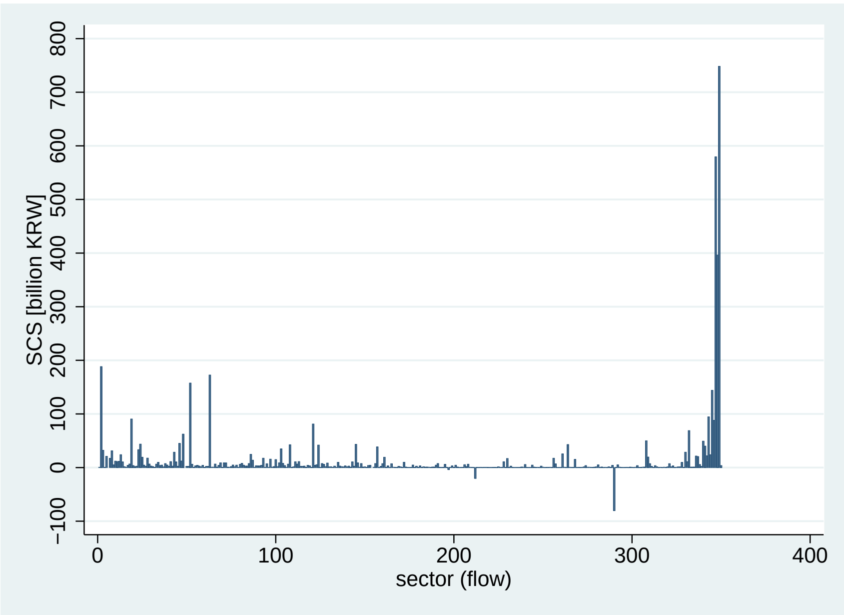


Figure 10: Sectoral distribution of SCS for productivity doubling of RMC sector (159th) for CES system. (Korea)

Table 3: CES Elasticities and Productivity Growths (Japan 2000–2005)

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Rice | 1.709 | 0.097 | 70 |
| Wheat, barley and the like | 2.952 * | 0.081 | 58 |
| Potatoes and sweet potatoes | 1.590 | −0.003 | 61 |
| Pulses | 1.904 | −0.153 | 53 |
| Vegitables | 1.715 | 0.136 | 76 |
| Fruits | 1.488 | −0.224 | 70 |
| Sugar crops | 2.133 | −0.116 | 55 |
| Crops for beverages | 1.140 | −1.153 | 47 |
| Other edible crops | 1.878 | −0.005 | 46 |
| Crops for feed and forage | 2.988 *** | −0.207 *** | 56 |
| Seeds and seedlings | 1.655 | −0.024 | 73 |
| Flowers and plants | 1.036 | −2.183 | 73 |
| Other inedible crops | 1.371 | −0.067 | 66 |
| Dairy cattle farming | 1.787 | 0.248 * | 76 |
| Hen eggs | 2.377 | 0.192 ** | 58 |
| Fowls and broilers | 2.199 * | 0.332 *** | 55 |
| Hogs | 0.706 | −0.772 | 69 |
| Beef cattle | 2.428 | −0.025 | 71 |
| Other livestock | 1.855 | 0.126 * | 70 |
| Veterinary service | 1.238 | −0.179 | 77 |
| Agricultural services (except veterinary service) | 1.199 | −0.200 | 96 |
| Silviculture | −0.043 | −0.183 ** | 88 |
| Logs | 0.532 | 0.521 | 71 |
| Special forest products (inc. hunting) | 1.420 | 0.446 | 63 |
| Fisheries | 1.648 *** | −0.011 | 90 |
| Marine culture | 1.717 ** | 0.092 | 90 |
| Inland water Culture | 1.373 | 0.049 | 82 |
| Metallic ores | 1.634 *** | −0.799 *** | 80 |
| Materials for ceramics | 0.913 | 1.372 ** | 96 |
| Gravel and quarrying | 1.409 | −0.046 | 96 |
| Crushed stones | 1.041 | −2.373 ** | 93 |
| Other non-metallic ores | 1.299 | 0.975 *** | 73 |
| Coal mining , crude petroleum and natural gas | 1.850 *** | −0.277 *** | 87 |
| Slaughtering and meat processing | 1.148 | 0.177 | 74 |
| Processed meat products | 1.358 | −0.021 | 95 |
| Bottled or canned meat products | 1.106 | 0.739 | 87 |
| Dairy farm products | 1.530 | 0.206 ** | 100 |
| Frozen fish and shellfish | 2.074 * | 0.449 *** | 78 |
| Salted, dried or smoked seafood | 1.348 | 0.278 | 90 |
| Bottled or canned seafood | 1.243 | 0.145 | 83 |
| Fish paste | 1.536 | −0.006 | 101 |
| Other processed seafood | 1.435 | 0.371 ** | 100 |
| Grain milling | 1.190 | 0.136 | 70 |
| Flour and other grain milled products | 1.413 | 0.459 *** | 82 |
| Noodles | 1.669 ** | 0.151 * | 106 |
| Bread | 1.664 ** | −0.015 | 109 |
| Confectionery | 1.807 *** | 0.080 | 119 |
| Bottled or canned vegetables and fruits | 1.227 | −0.288 | 86 |
| Preserved agricultural foodstuffs (other than bottled or canned) | 1.370 | 0.305 ** | 96 |
| Sugar | 1.492 ** | −0.044 | 81 |
| Starch | 1.417 | 0.339 * | 73 |
| Dextrose, syrup and isomerized sugar | 1.405 ** | 0.133 ** | 76 |
| Vegetable oils and meal | 1.200 | 0.668 *** | 105 |
| Animal oils and fats | 1.421 | −0.136 | 75 |
| Condiments and seasonings | 1.310 | 0.067 | 112 |
| Prepared frozen foods | 1.535 | 0.209 | 100 |
| Retort foods | 1.543 * | 0.012 | 90 |
| Dishes, sushi and lunch boxes | 1.761 ** | 0.165 *** | 114 |
| School lunch (public) ** | 1.153 | 0.094 | 73 |
| School lunch (private) * | 1.426 | −0.551 ** | 42 |
| Other foods | 1.278 | 0.375 * | 109 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Refined sake | 1.028 | −2.946 | 89 |
| Beer | 1.477 | −0.002 | 89 |
| Whiskey and brandy | 2.601 * | −0.071 | 86 |
| Other liquors | 1.942 | −0.085 | 95 |
| Tea and roasted coffee | 1.373 | 0.653 *** | 89 |
| Soft drinks | 1.653 | 0.181 | 95 |
| Manufactured ice | 0.984 | −1.444 | 61 |
| Feeds | 1.171 | 1.984 *** | 105 |
| Organic fertilizers, n.e.c. | 0.454 | −0.521 *** | 79 |
| Tobacco | 1.567 | 0.404 ** | 99 |
| Fiber yarns | 1.851 ** | −0.094 | 92 |
| Cotton and staple fiber fabrics (inc. fabrics of synthetic spun fibers) | 1.159 | −0.805 ** | 78 |
| Silk and artificial silk fabrics (inc. fabrics of synthetic filament fibers) | 1.261 | −0.699 *** | 79 |
| Woolen fabrics, hemp fabrics and other fabrics | 0.792 | −0.585 | 77 |
| Knitting fabrics | 0.906 | 0.912 * | 86 |
| Yarn and fabric dyeing and finishing (processing on commission only) | 0.954 | 1.141 | 107 |
| Ropes and nets | 1.454 | −0.152 | 92 |
| Carpets and floor mats | 0.702 | 0.651 *** | 83 |
| Fabricated textiles for medical use | 1.414 | −0.107 | 66 |
| Other fabricated textile products | 1.426 | 0.206 ** | 116 |
| Woven fabric apparel | 1.577 * | −0.065 | 99 |
| Knitted apparel | 2.031 * | −0.084 | 105 |
| Other wearing apparel and clothing accessories | 1.800 * | −0.270 *** | 107 |
| Bedding | 1.478 | −0.199 | 89 |
| Other ready-made textile products | 1.390 | −0.005 | 99 |
| Timber | 1.241 | 0.348 | 77 |
| Plywood | 1.713 ** | −0.126 | 84 |
| Wooden chips | 1.626 * | −0.350 *** | 62 |
| Other wooden products | 1.716 *** | −0.035 | 158 |
| Wooden furniture and fixtures | 2.086 *** | 0.004 | 143 |
| Wooden fixtures | 1.223 | 0.218 | 112 |
| Metallic furniture and fixture | 1.775 ** | 0.103 | 122 |
| Pulp | 2.634 ** | −0.028 | 102 |
| Paper | 1.340 | 0.016 | 114 |
| Paperboard | 1.341 | −0.079 | 108 |
| Corrugated cardboard | 1.324 | −0.413 | 82 |
| Coated paper and building (construction) paper | 1.197 | −0.063 | 108 |
| Corrugated card board boxes | 1.234 | −0.271 | 89 |
| Other paper containers | 1.122 | −0.136 | 96 |
| Paper textile for medical use | 1.428 | −0.105 | 104 |
| Other pulp, paper and processed paper products | 1.517 ** | 0.035 | 123 |
| Printing, plate making and book binding | 1.581 | 0.086 | 125 |
| Chemical fertilizer | 1.608 * | 0.012 | 111 |
| Industrial soda chemicals | 1.147 | 0.475 | 94 |
| Inorganic pigment | 1.581 ** | 0.233 *** | 102 |
| Compressed gas and liquefied gas | 1.593 * | 0.041 | 79 |
| Salt | 0.885 | −1.737 | 73 |
| Other industrial inorganic chemicals | 1.643 ** | 0.026 | 114 |
| Petrochemical basic products | 1.798 * | −0.200 | 87 |
| Petrochemical aromatic products (except synthetic resin) | 1.326 | 0.356 | 83 |
| Aliphatic intermediates | 1.461 * | 0.214 ** | 107 |
| Cyclic intermediates | 1.784 *** | 0.367 *** | 103 |
| Synthetic rubber | 1.465 | 0.192 | 98 |
| Methane derivatives | 1.210 | 0.085 | 82 |
| Oil and fat industrial chemicals | 1.555 * | 0.047 | 89 |
| Plasticizers | 2.262 *** | −0.153 *** | 82 |
| Synthetic dyes | 1.868 *** | 0.165 *** | 95 |
| Other industrial organic chemicals | 1.687 * | 0.115 | 116 |
| Thermo-setting resins | 1.058 | 2.743 *** | 104 |
| Thermoplastics resins | 1.190 | 0.945 *** | 99 |
| High function resins | 0.905 | −0.217 | 96 |
| Other resins | 0.961 | −2.054 | 94 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Rayon and acetate | 0.990 | 14.826 ** | 86 |
| Synthetic fibers | 1.636 * | −0.065 | 97 |
| Medicaments | 1.976 * | 0.132 | 133 |
| Soap, synthetic detergents and surface active agents | 1.086 | −0.678 | 111 |
| Cosmetics, toilet preparations and dentifrices | 1.576 * | 0.074 | 103 |
| Paint and varnishes | 1.703 *** | 0.047 | 123 |
| Printing ink | 1.348 | 0.242 * | 100 |
| Photographic sensitive materials | 1.581 ** | 0.283 ** | 104 |
| Agricultural chemicals | 1.307 | −0.007 | 92 |
| Gelatin and adhesives | 1.364 | 0.114 | 119 |
| Other final chemical products | 1.782 *** | 0.048 | 148 |
| Petroleum refinery products (inc. greases) | 1.353 | 1.768 *** | 98 |
| Coal products | 1.979 ** | 0.593 *** | 89 |
| Paving materials | 1.183 | −0.204 | 89 |
| Plastic products | 1.431 | −0.090 | 167 |
| Tires and inner tubes | 1.517 * | 0.072 | 100 |
| Rubber footwear | 1.513 | −0.267 | 105 |
| Plastic footwear | 1.965 *** | −0.095 ** | 106 |
| Other rubber products | 1.740 *** | 0.052 | 123 |
| Leather footwear | 0.886 | 0.567 | 95 |
| Leather and fur skins | 0.874 | 0.373 | 87 |
| Miscellaneous leather products | 1.397 | −0.250 ** | 119 |
| Sheet glass and safety glass | 1.021 | 0.246 | 107 |
| Glass fiber and glass fiber products, n.e.c. | 1.774 *** | −0.002 | 104 |
| Other glass products | 2.006 *** | −0.060 | 105 |
| Cement | 1.577 ** | 0.000 | 101 |
| Ready mixed concrete | 0.869 | 0.679 * | 88 |
| Cement products | 1.223 | −0.121 | 116 |
| Pottery, china and earthenware | 2.073 *** | −0.089 * | 117 |
| Clay refractories | 1.656 *** | −0.022 | 107 |
| Other structural clay products | 1.485 ** | 0.010 | 105 |
| Carbon and graphite products | 1.308 | −0.050 | 104 |
| Abrasive | 1.363 * | 0.025 | 124 |
| Miscellaneous ceramic, stone and clay products | 1.455 *** | 0.004 | 145 |
| Pig iron | 1.600 ** | −0.680 * | 167 |
| Ferro alloys | 1.652 * | −0.823 | 83 |
| Crude steel (converters) | 2.635 *** | −0.377 *** | 97 |
| Crude steel (electric furnaces) | 1.870 ** | −0.226 | 94 |
| Hot rolled steel | 2.138 *** | −0.207 | 95 |
| Steel pipes and tubes | 0.973 | −11.035 * | 96 |
| Cold-finished steel | 1.422 | 0.315 | 95 |
| Coated steel | 1.981 *** | 0.004 | 98 |
| Cast and forged steel | 1.013 | 22.002 *** | 83 |
| Cast iron pipes and tubes | 1.805 ** | −0.102 | 88 |
| Cast and forged materials (iron) | 2.091 *** | −0.026 | 131 |
| Iron and steel shearing and slitting | 2.379 *** | −0.265 * | 81 |
| Other iron or steel products | 1.345 * | 0.231 | 79 |
| Copper | 2.110 ** | −0.448 | 75 |
| Lead and zinc (inc. regenerated lead) | 1.340 | 0.659 * | 83 |
| Aluminum (inc. regenerated aluminum) | 1.061 | −3.066 | 80 |
| Other non-ferrous metals | 0.192 | −0.529 | 149 |
| Electric wires and cables | 1.566 *** | 0.051 | 119 |
| Optical fiber cables | 1.634 ** | −0.360 *** | 113 |
| Rolled and drawn copper and copper alloys | 1.829 ** | −0.166 | 81 |
| Rolled and drawn aluminum | 1.824 * | −0.063 | 84 |
| Non-ferrous metal castings and forgings | 1.615 ** | −0.034 | 121 |
| Nuclear fuels | 1.085 | 1.572 ** | 51 |
| Other non-ferrous metal products | 2.152 ** | −0.549 ** | 86 |
| Metal products for construction | 1.497 ** | 0.040 | 134 |
| Metal products for architecture | 1.142 | 0.195 | 122 |
| Gas and oil appliances and heating and cooking apparatus | 1.568 *** | 0.069 | 131 |
| Bolts, nuts, rivets and springs | 1.763 *** | −0.060 | 130 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Metal containers, fabricated plate and sheet metal | 1.780 *** | 0.104 ** | 132 |
| Plumber's supplies, powder metallurgy products and tools | 1.596 *** | 0.057 | 126 |
| Other metal products | 1.774 *** | 0.087 * | 143 |
| Boilers | 1.646 ** | 0.217 *** | 118 |
| Turbines | 1.689 *** | 0.783 *** | 117 |
| Engines | 1.859 *** | −0.026 | 127 |
| Conveyors | 1.408 ** | −0.005 | 136 |
| Refrigerators and air conditioning apparatus | 1.375 | 0.410 *** | 140 |
| Pumps and compressors | 2.111 *** | 0.085 ** | 127 |
| Machinists' precision tools | 1.285 | 0.452 *** | 126 |
| Other general industrial machinery and equipment | 1.386 * | 0.116 | 138 |
| Machinery and equipment for construction and mining | 1.308 | −0.220 | 129 |
| Chemical machinery | 1.528 ** | −0.176 ** | 130 |
| Industrial robots | 1.520 ** | −0.117 | 122 |
| Metal machine tools | 1.469 | −0.234 * | 127 |
| Metal processing machinery | 1.654 *** | −0.192 *** | 126 |
| Machinery for agricultural use | 1.576 ** | 0.030 | 140 |
| Textile machinery | 2.218 *** | −0.169 *** | 136 |
| Food processing machinery and equipment | 1.562 ** | −0.116 * | 122 |
| Semiconductor making equipment | 1.453 ** | 0.099 | 140 |
| Other special machinery for industrial use | 1.646 ** | 0.026 | 144 |
| Metal molds | 1.894 *** | 0.035 | 125 |
| Bearings | 1.627 *** | 0.086 | 112 |
| Other general machines and parts | 1.644 *** | −0.013 | 141 |
| Copy machine | 1.210 | −0.609 *** | 130 |
| Other office machines | 1.154 | 0.473 | 131 |
| Machinery for service industry | 1.378 ** | −0.233 ** | 127 |
| Rotating electrical equipment | 1.457 ** | −0.172 ** | 125 |
| Transformers and reactors | 1.600 ** | −0.102 | 122 |
| Relay switches and switchboards | 1.270 | −0.072 | 139 |
| Wiring devices and supplies | 1.784 *** | −0.019 | 126 |
| Electrical equipment for internal combustion engines | 1.483 ** | −0.021 | 128 |
| Other electrical devices and parts | 1.388 ** | −0.246 *** | 140 |
| Applied electronic equipment | 1.455 ** | 0.160 * | 131 |
| Electric measuring instruments | 1.362 * | −0.399 *** | 126 |
| Electric bulbs | 1.570 ** | 0.125 * | 101 |
| Electric lighting fixtures and apparatus | 0.755 | 0.224 | 123 |
| Batteries | 1.640 ** | −0.317 *** | 127 |
| Other electrical devices and parts | 2.059 *** | 0.121 | 123 |
| Household air-conditioners | 1.246 | 0.509 ** | 148 |
| Household electric appliances (except air-conditioners) | 1.333 ** | 0.182 | 151 |
| Video recording and playback equipment | 2.007 *** | 0.773 *** | 134 |
| Electric audio equipment | 1.376 | 0.411 *** | 144 |
| Radio and television sets | 0.900 | −4.189 ** | 123 |
| Wired communication equipment | 2.164 *** | −0.243 *** | 148 |
| Cellular phones | 1.143 | 3.108 | 145 |
| Radio communication equipment (except cellular phones) | 1.367 | −0.265 ** | 147 |
| Other communication equipment | 0.758 | −0.323 * | 139 |
| Personal Computers | 1.455 * | 0.647 | 124 |
| Electronic computing equipment (except personal computers) | 1.668 *** | 0.268 | 124 |
| Electronic computing equipment (accessory equipment) | 1.871 *** | 0.412 *** | 130 |
| Semiconductor devices | 1.476 | 0.013 | 122 |
| Integrated circuits | 1.269 | −0.693 | 124 |
| Electron tubes | 1.825 *** | 0.018 | 114 |
| Liquid crystal element | 2.296 *** | 1.269 *** | 114 |
| Magnetic tapes and discs | 1.479 | 0.348 | 119 |
| Other electronic components | 1.746 *** | −0.049 | 150 |
| Passenger motor cars | 1.703 ** | −0.135 * | 121 |
| Trucks, buses and other cars | 1.488 | 0.277 *** | 123 |
| Two-wheel motor vehicles | 1.088 | −0.187 | 97 |
| Motor vehicle bodies | 1.592 * | −0.139 | 123 |
| Internal combustion engines for motor vehicles and parts | 1.803 *** | 0.010 | 129 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Motor vehicle parts and accessories | 1.701 *** | 0.137 ** | 150 |
| Steel ships | 1.451 *** | 0.307 *** | 155 |
| Ships (except steel ships) | 1.081 | 2.768 | 140 |
| Internal combustion engines for vessels | 1.808 ** | 0.057 | 113 |
| Repair of ships | 1.378 ** | 0.239 *** | 140 |
| Rolling stock | 1.808 *** | −0.284 *** | 136 |
| Repair of rolling stock | 1.712 *** | −0.052 | 115 |
| Aircrafts | 1.684 ** | −0.103 | 119 |
| Repair of aircrafts | 1.657 | −0.308 ** | 60 |
| Bicycles | 1.728 | −0.233 ** | 111 |
| Other transport equipment | 1.973 *** | −0.089 | 138 |
| Camera | 0.628 | −0.212 | 113 |
| Other photographic and optical instruments | 0.423 ** | −0.014 | 125 |
| Watches and clocks | 1.471 *** | −0.339 *** | 119 |
| Professional and scientific instruments | 1.289 | −0.010 | 118 |
| Analytical instruments, testing machine, measuring instruments | 0.823 | 0.003 | 149 |
| Medical instruments | 0.090 *** | −0.052 | 149 |
| Toys and games | 1.123 | 0.895 * | 133 |
| Sporting and athletic goods | 1.578 ** | 0.077 | 133 |
| Musical instruments | 1.237 | 0.137 | 112 |
| Audio and video records, other information recording media | 1.488 * | −0.135 * | 93 |
| Stationery | 1.030 | −0.796 | 125 |
| Jewelry and adornments | 1.142 | 0.559 ** | 172 |
| ”Tatami” (straw matting) and straw products | 1.525 | −0.390 * | 67 |
| Ordnance | 1.358 | 0.235 | 122 |
| Miscellaneous manufacturing products | 1.622 *** | 0.071 | 178 |
| Residential construction (wooden) | 1.445 | 0.132 | 153 |
| Residential construction (non-wooden) | 1.202 | 0.231 | 157 |
| Non-residential construction (wooden) | 1.183 | 0.109 | 149 |
| Non-residential construction (non-wooden) | 1.316 | 0.124 | 159 |
| Repair of construction | 1.212 | 0.190 | 144 |
| Public construction of roads | 0.855 | −0.437 | 153 |
| Public construction of rivers, drainages and others | 1.063 | 0.363 | 153 |
| Agricultural public construction | 2.039 * | 0.062 | 142 |
| Railway construction | 0.740 | −0.488 *** | 146 |
| Electric power facilities construction | 0.800 | −0.029 | 148 |
| Telecommunication facilities construction | 1.309 | 0.115 | 138 |
| Other civil engineering and construction | 0.931 | −0.922 | 150 |
| Electricity | 1.476 * | −0.052 | 96 |
| Private power generation | 1.007 | −32.744 | 78 |
| Gas supply | 1.674 | 0.126 | 91 |
| Steam and hot water supply | 0.100 | 0.178 | 53 |
| Water supply | 1.315 | −0.033 | 96 |
| Industrial water supply | 1.117 | 1.011 * | 62 |
| Sewage disposal ** | 1.734 *** | −0.013 | 84 |
| Waste management services (public) ** | 1.522 | −0.610 *** | 87 |
| Waste management services (private) | 1.421 | 0.231 ** | 87 |
| Wholesale trade | 1.334 | −0.183 * | 119 |
| Retail trade | 1.413 | −0.483 *** | 114 |
| Financial service | 0.275 * | 0.260 *** | 99 |
| Life insurance | 1.023 | 2.589 | 86 |
| Non-life insurance | 0.855 | −1.897 *** | 79 |
| Real estate agencies and managers | 0.927 | −0.236 | 81 |
| Real estate rental service | 0.304 | −0.210 * | 84 |
| House rent | 0.857 | −0.062 | 87 |
| Railway transport (passengers) | 2.086 *** | −0.040 | 110 |
| Railway transport (freight) | 1.918 *** | 0.154 *** | 99 |
| Bus transport service | 0.784 | 0.613 ** | 86 |
| Hired car and taxi transport | 0.430 | 0.118 | 84 |
| Road freight transport(exceptSelf-transport by private cars) | 1.159 | −0.699 ** | 91 |
| Ocean transport | 1.173 | 0.974 | 101 |
| Coastal and inland water transport | 1.247 | −0.630 *** | 103 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Harbor transport service | 1.105 | −0.759 *** | 94 |
| Air transport | 1.534 | 0.248 ** | 103 |
| Consigned freight forwarding | −0.732 ** | −0.239 * | 91 |
| Storage facility service | 1.602 ** | −0.404 *** | 103 |
| Packing service | 1.299 | −0.141 | 101 |
| Facility service for road transport | 1.088 | −0.161 | 85 |
| Port and water traffic control ** | 1.078 | −0.604 | 83 |
| Services relating to water transport | 1.540 | −0.258 ** | 84 |
| Airport and air traffic control (public) ** | 1.412 | −0.099 | 86 |
| Airport and air traffic control (industrial) | 1.143 | −0.572 ** | 82 |
| Services relating to air transport | 1.195 | −0.057 | 108 |
| Travel agency and other services relating to transport | 0.161 | −0.014 | 73 |
| Postal service and mail delivery | 1.423 | 0.394 * | 90 |
| Fixed telecommunication | 0.750 | 0.573 ** | 101 |
| Mobile telecommunication | 1.924 | −0.144 | 73 |
| Other services relating to communication | 2.444 *** | 0.019 | 63 |
| Public broadcasting | 1.188 | −0.402 * | 88 |
| Private broadcasting | 1.101 | −1.329 *** | 91 |
| Cable broadcasting | 1.116 | −1.439 *** | 81 |
| Information services | 1.459 | 0.032 | 98 |
| Internet based services | | | -2 |
| Image information production and distribution industry | 1.678 ** | −0.201 ** | 117 |
| Newspaper | 1.529 ** | 0.007 | 97 |
| Publication | 1.470 * | 0.029 | 103 |
| News syndicates and private detective agencies | 1.434 * | −0.045 | 72 |
| Public administration (central) ** | 1.603 *** | 0.223 *** | 217 |
| Public administration (local) ** | 1.228 | −0.301 ** | 124 |
| School education (public) ** | 1.849 | −0.013 | 106 |
| School education (private) * | 1.716 | −0.563 *** | 107 |
| Social education (public) ** | 1.812 * | −0.238 *** | 91 |
| Social education (private, non-profit) * | 1.321 | −0.464 | 76 |
| Other educational and training institutions (public) ** | 1.418 | −1.458 *** | 90 |
| Other educational and training institutions (profit-making) | 1.748 ** | 0.079 | 72 |
| Research institutes for natural science (pubic) ** | 2.090 * | −0.745 *** | 88 |
| Research institutes for cultural and social science (public) ** | 1.995 | −0.968 *** | 62 |
| Research institutes for natural sciences (private, non-profit) * | 1.380 | −2.144 *** | 59 |
| Research institutes for cultural and social science (private,non-profit) * | 1.183 | −5.944 *** | 47 |
| Research institutes for natural sciences (profit-making) | 2.108 ** | −0.855 *** | 91 |
| Research institutes for cultural and social science (profit-making) | 2.510 | −0.211 ** | 50 |
| Research and development (intra-enterprise) | 1.461 ** | −0.317 *** | 124 |
| Medical service (public) | 1.808 *** | −0.087 ** | 151 |
| Medical service (non-profit foundations, etc.) | 1.812 *** | −0.021 | 152 |
| Medical service (medical corporations, etc.) | 1.622 ** | 0.168 ** | 154 |
| Health and hygiene (public) ** | 1.496 *** | 0.033 | 89 |
| Health and hygiene (profit-making) | 1.509 ** | 0.059 | 92 |
| Social insurance (public) ** | 1.292 | −0.274 ** | 68 |
| Social insurance (private, non-profit) * | 1.370 | −0.190 ** | 68 |
| Social welfare (public) ** | 1.479 ** | −0.201 *** | 140 |
| Social welfare (private, non-profit) * | 1.460 *** | −0.072 | 141 |
| Social welfare (profit-making) | 1.268 *** | 0.251 *** | 141 |
| Nursing care (In-home) | 1.552 *** | −0.095 ** | 151 |
| Nursing care (In-facility) | 1.585 *** | 0.101 ** | 157 |
| Private non-profit institutions serving enterprises | 1.586 * | −0.450 *** | 89 |
| Private non-profit institutions serving households, n.e.c. * | 1.391 * | 0.242 *** | 103 |
| Advertising services | 1.964 *** | 0.018 | 101 |
| Goods rental and leasing (except car rental) | 1.126 | −1.000 | 111 |
| Car rental and leasing | 1.448 | 0.201 | 76 |
| Repair of motor vehicles | 1.442 * | −0.052 | 112 |
| Repair of machine | 1.622 ** | −0.153 * | 143 |
| Building maintenance services | 1.260 | −0.264 | 80 |
| Judicial, financial and accounting services | 1.316 | 0.290 | 78 |
| Civil engineering and construction services | 1.632 | −0.145 | 90 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Worker dispatching services | 1.469 | 0.400 *** | 79 |
| Other business services | 2.098 *** | 0.270 *** | 120 |
| Movie theaters | 0.530 | −0.129 | 74 |
| Performances (except otherwise claasified), theatrical comranies | 1.321 | 0.129 | 106 |
| Amusement and recreation facilities | 1.380 | −0.107 | 100 |
| Stadiums and companies of bicycle, horse, motorcar and motorboat races | 1.735 | −0.313 *** | 103 |
| Sport facility service, public gardens and amusement parks | 1.571 | −0.220 * | 114 |
| Other amusement and recreation services | 1.185 | −0.975 ** | 103 |
| General eating and drinking places (except coffee shops) | 1.211 | −0.119 | 146 |
| Coffee shops | 1.183 | −0.326 * | 137 |
| Eating and drinking places for pleasures | 1.281 | −0.098 | 145 |
| Accommodations | 1.825 *** | −0.084 ** | 159 |
| Cleaning | 1.655 ** | −0.103 * | 86 |
| Barber shops | 1.657 *** | −0.148 *** | 84 |
| Beauty shops | 1.459 * | −0.126 | 89 |
| Public baths | 1.544 * | −0.188 ** | 92 |
| Other cleaning, barber shops, beauty shops and public baths | 1.186 | −1.225 ** | 88 |
| Photographic studios | 1.499 | −0.399 *** | 96 |
| Ceremonial occasions | 1.087 | 1.733 *** | 152 |
| Miscellaneous repairs, n.e.c. | 0.575 | 0.099 | 114 |
| Supplementary tutorial schools, instruction services for arts, culture and technical skills | 1.431 | −0.101 | 110 |
| Other personal services | 1.925 * | −0.155 ** | 111 |
| Office supplies | 2.608 *** | −0.015 | 27 |
| Activities not elsewhere classified | 3.575 *** | 0.047 | 177 |

Table 4: CES Elasticities and Productivity Growths (Korea 2000–2005)

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Unmilled rice | 0.378 | 0.178 | 78 |
| Barley | 1.763 | 0.284 | 59 |
| Wheat | 1.786 | 0.643 ** | 25 |
| Misc. cereals | 0.367 | −0.312 | 46 |
| Vegetables | 1.216 | −0.383 | 101 |
| Fruits | 1.029 | −11.848 ** | 90 |
| Pulses | 1.867 | 0.276 * | 49 |
| Potatoes | 1.139 | −0.725 | 46 |
| Oleaginous crops | 1.760 | −0.376 ** | 46 |
| Cultivated medicinal herbs | 0.762 | 1.712 ** | 58 |
| Other edible crops | 2.586 ** | −0.139 | 54 |
| Cotton and hemp | 0.981 | −1.223 | 22 |
| Horticultural specialities | 1.963 | 0.063 | 101 |
| Natural rubber | | | |
| Seeds and seedlings | 0.638 | −0.549 * | 95 |
| Other Inedible crops | 0.292 | 1.230 * | 16 |
| Dairy farming | 0.471 | −0.360 ** | 117 |
| Beef cattle | 0.506 | −0.941 ** | 119 |
| Pigs | 0.509 | −0.788 ** | 120 |
| Poultry and birds | 0.987 | −16.635 ** | 122 |
| Other animals | 0.723 | −0.836 | 102 |
| Operation of timber tracts | 0.470 | 0.004 | 92 |
| Raw timber | 0.587 | 0.178 | 46 |
| Edible forest products | 0.698 | 0.308 | 74 |
| Misc. forest products | 1.214 | −0.617 | 68 |
| Fishing | 1.289 | 0.246 | 160 |
| Aquaculture | 1.160 | 1.010 *** | 126 |
| Agriculture, forestry and fishing related services | 1.681 | −0.770 *** | 131 |
| Anthracite | 2.325 *** | 0.122 | 128 |
| Bituminous coal | | | |
| Crude petroleum and Natural gas | | | |
| Iron ores | 1.801 | −0.060 | 78 |
| Copper ores | | | |
| Lead and zinc ores | 2.107 | −0.210 | 7 |
| Misc. non-ferrous metal ores | 2.328 | 0.421 *** | 48 |
| Sand and gravel | 2.520 ** | −0.201 | 109 |
| Crushed and broken stone abd Other bulk stones | 1.787 * | −0.044 | 116 |
| Limestone | 1.648 | 0.067 | 122 |
| Materials for ceramics | 1.494 | −0.003 | 113 |
| Crude salt | 1.782 | 0.312 *** | 91 |
| Misc. non-metallic minerals | 2.262 *** | 0.185 | 104 |
| Slaughtering and meat processing | 1.255 | 0.280 | 101 |
| Poultry slaughtering and processing | 1.428 | 0.189 | 91 |
| Prepared meat products | 1.650 | 0.274 ** | 138 |
| Dairy products | 1.971 ** | 0.157 * | 140 |
| Canned seafoods | 1.331 | 1.047 * | 106 |
| Frozen fish and seafoods | 1.756 | −1.440 *** | 98 |
| Salted, dried and smoked seafoods | 3.290 * | 0.084 | 94 |
| Misc. processed seafoods | 1.360 | 1.289 *** | 109 |
| Polished rice | 1.285 | 0.473 | 92 |
| Polished barley | 1.209 | −0.250 | 69 |
| Flour and cereal preparations | 1.743 | −0.519 ** | 98 |
| Raw sugar | | | |
| Refined sugar | 1.533 | −0.253 | 97 |
| Starches | 2.220 ** | −0.137 * | 98 |
| Glucose, glucose syrup and maltose | 1.611 | 0.118 | 106 |
| Bakery and confectionery products | 1.819 * | 0.213 ** | 170 |
| Noodles | 1.294 | 0.512 * | 131 |
| Seasonings | 1.636 | 0.037 | 149 |
| Soy sauce ad bean paste | 1.750 * | 0.008 | 123 |
| Animal and marine fats and oils | 1.188 | 0.951 * | 103 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Vegetable fats and oils, and processed edible refined oil | 1.514 | 0.106 | 123 |
| Canned or cured fruits and vegetables | 1.761 * | −0.034 | 135 |
| Coffee and tea | 1.550 | −0.324 ** | 125 |
| Ginseng products | 1.686 * | 0.089 | 100 |
| Malt and yeast | 1.629 | −0.116 | 86 |
| Bean curd and Misc. foodstuffs | 1.572 | 0.192 | 158 |
| Ethyl alcohol for beverages | 1.666 | 0.070 | 104 |
| Blended and distilled sojoo | 1.631 | −0.035 | 117 |
| Beer | 0.993 | −38.630 *** | 106 |
| Other liquors | 1.740 | 0.018 | 124 |
| Soft drinks and Manufactured ice | 1.205 | 0.562 | 137 |
| Prepared livestock feeds | 1.713 * | 0.069 | 150 |
| Tobacco products | 1.950 | −0.538 ** | 98 |
| Woolen yarn | 1.347 | 0.712 *** | 109 |
| Cotton yarn | 0.999 | 37.363 | 123 |
| Silk and hempen yarn | 1.006 | 2.922 | 82 |
| Regenerated fiber yarn | 1.472 | 1.128 *** | 82 |
| Synthetic fiber yarn | 1.903 ** | −0.067 | 120 |
| Thread and other fiber yarns | 1.915 *** | −0.004 | 110 |
| Woolen fabrics | 1.407 | −0.031 | 110 |
| Cotton fabrics | 1.083 | −1.519 * | 123 |
| Silk and hempen fabrics | 1.982 ** | 0.196 | 106 |
| Regenerated fiber fabrics | 1.527 | 0.282 | 100 |
| Synthetic fiber fabrics | 1.852 ** | 0.097 | 124 |
| Other fiber fabrics | 1.384 | −0.132 | 116 |
| Knitted fabrics | 1.928 ** | 0.064 | 107 |
| Fiber bleaching and dyeing | 1.949 ** | 0.058 | 115 |
| Knitted wearing apparels | 1.199 | −0.706 | 124 |
| Knitted clothing accessories | 2.204 ** | 0.100 | 112 |
| Textile wearing apparels and Clothing accessories | 0.930 | 1.066 | 137 |
| Leather wearing apparels | 1.845 * | 0.116 | 104 |
| Fur and Fur wearing apparels | 1.318 | 0.509 *** | 121 |
| Textile products and Misc. textile products | 1.613 | −0.249 | 154 |
| Cordage, rope, and fishing nets | 1.386 | 0.057 | 111 |
| Leather | 1.831 ** | 0.260 ** | 125 |
| Luggage and handbags | 2.172 *** | 0.161 *** | 114 |
| Footwear | 1.836 *** | −0.139 * | 127 |
| Other leather products | 1.858 * | 0.028 | 87 |
| Lumber | 2.081 ** | −0.080 | 101 |
| Plywood | 1.769 * | −0.067 | 118 |
| Reconstituted and densified wood | 1.597 | −0.409 ** | 113 |
| Wooden products for construction | 1.953 *** | −0.164 ** | 110 |
| Wooden containers and Other wooden products | 2.034 ** | 0.224 ** | 120 |
| Pulp | 1.526 * | 0.273 | 108 |
| Newsprint | 1.708 | −0.108 | 115 |
| Printing paper | 1.613 | −0.122 | 138 |
| Other raw paper and paperboard | 1.808 *** | 0.043 | 146 |
| Corrugated paper and solid fiber boxes | 1.662 ** | −0.040 | 115 |
| Paper containers | 1.927 *** | 0.107 | 128 |
| Stationery paper and office paper | 1.497 * | 0.032 | 121 |
| Other paper products | 1.597 * | 0.054 | 156 |
| Printing | 1.579 *** | 0.081 | 139 |
| Reproduction of recorded media | 1.987 *** | 0.123 ** | 132 |
| Coal briquettes | 1.524 | 0.706 | 74 |
| Coke and other coal products | 1.340 | 0.017 | 119 |
| Naphtha | 1.612 | −0.697 ** | 117 |
| Gasoline and Jet oil | 1.698 ** | −0.234 | 123 |
| Kerosene | 1.633 | −0.283 | 122 |
| Light oil | 1.349 | −0.213 | 122 |
| Heavy oil | 1.626 | −0.359 | 121 |
| Liquefied petroleum gas | 1.390 | −0.038 | 121 |
| Lubricants | 1.736 * | 0.180 | 127 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Misc. petroleum refinery products | 1.793 * | −0.011 | 123 |
| Petrochemical basic products | 1.305 | 0.883 | 121 |
| Petrochemical intermediate products and Other basic organic chemicals | 1.876 ** | 0.042 | 159 |
| Coal chemicals | 0.394 | −0.521 | 105 |
| Industrial gases | 1.714 | −0.042 | 120 |
| Basic inorganic chemicals | 1.280 | 0.301 | 157 |
| Synthetic resins | 1.534 | 0.587 *** | 151 |
| Synthetic rubber | 1.450 | 0.646 ** | 116 |
| Regenerated cellulose fibers | 1.330 | 0.124 | 95 |
| Synthetic fibers | 1.701 * | −0.073 | 124 |
| Nitrogen compounds | 1.759 ** | 0.025 | 110 |
| Fertilizers | 1.664 | 0.187 | 138 |
| Pesticides and other agricultural chemicals | 1.510 | 0.195 | 130 |
| Medicaments | 1.998 *** | 0.207 ** | 171 |
| Cosmetics and dentifrices | 1.974 ** | 0.255 ** | 161 |
| Soap and detergents | 1.499 | 0.257 * | 147 |
| Dyes, pigments, and tanning materials | 1.390 | 0.544 ** | 141 |
| Paints, varnishes, and allied products | 1.700 ** | 0.118 | 151 |
| Printing ink | 2.049 *** | 0.190 *** | 123 |
| Adhesives, gelatin and sealants | 1.882 ** | −0.021 | 139 |
| Explosives and fireworks products | 1.637 ** | −0.156 | 135 |
| Recording media and Photographic chemical products | 1.853 *** | 0.031 | 138 |
| Misc. chemical products | 1.589 ** | 0.245 ** | 168 |
| Primary plastic products | 1.625 | 0.251 * | 151 |
| Industrial plastic products | 1.674 ** | 0.014 | 163 |
| Household articles of plastic material | 1.721 ** | 0.032 | 120 |
| Tires and tubes | 1.477 | −0.189 | 140 |
| Rubber products | 1.763 *** | −0.022 | 150 |
| Sheet glass and primary glass products | 1.985 *** | 0.088 | 125 |
| Industrial glass products | 2.121 *** | 0.292 ** | 165 |
| Household glass products and others | 1.940 *** | 0.143 * | 132 |
| Pottery | 1.560 * | 0.177 | 151 |
| Refractory ceramic products | 1.332 | −0.102 | 142 |
| Clay products for construction | 1.800 ** | 0.285 ** | 136 |
| Cement | 2.086 *** | 0.070 | 150 |
| Ready mixed concrete | 2.040 *** | 0.030 | 128 |
| Concrete blocks, bricks, and other concrete products | 1.891 *** | 0.182 *** | 140 |
| Lime, gypsum, and plaster products | 1.813 * | 0.282 *** | 130 |
| Cut stone & stone products | 1.376 | 0.195 | 130 |
| Asbestos and mineral wool products | 1.754 ** | 0.212 ** | 141 |
| Abrasives | 1.710 ** | 0.074 | 138 |
| Asphalts | 1.582 | 0.164 | 121 |
| Misc. nonmetallic minerals products | 1.680 * | 0.152 | 136 |
| Pig iron | 1.922 *** | −0.171 | 134 |
| Ferroalloys | 0.819 | −1.402 | 108 |
| Steel ingots and semifinished products | 0.887 | −2.770 ** | 140 |
| Steel rods and bars | 1.616 | 0.160 | 124 |
| Section steel | 1.520 ** | 0.340 * | 117 |
| Rails and wires | 1.115 | 1.781 | 127 |
| Hot rolled steel plates and sheets | 0.576 | −0.661 * | 135 |
| Steel pipe and tubes, except foundry iron pipe and tubes | 1.025 | 9.495 | 138 |
| Cold rolled steel sheet, strip, and bars | 0.720 | −0.294 | 143 |
| Iron foundries and foundry iron pipe and tubes | 1.840 *** | −0.006 | 148 |
| Forgings | 2.125 *** | −0.289 ** | 118 |
| Coated steel plates | 1.210 | 0.032 | 140 |
| Misc. primary iron and steel products | 1.681 | 0.186 | 113 |
| Copper ingots | 1.526 | 0.312 | 120 |
| Aluminium ingots | 0.788 | −0.232 | 120 |
| Lead and zinc ingots | 1.125 | 2.700 *** | 132 |
| Gold and silver ingots | 2.860 *** | −0.186 * | 108 |
| Other nonferrous metal ingots | 1.697 * | −0.097 | 117 |
| Primary copper products | 1.537 | −0.080 | 130 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Primary aluminium products | 1.437 | 0.288 * | 140 |
| Other nonferrous metal casting and forgings, and primary nonferrous metals | 1.560 | 0.175 | 125 |
| Metal products for construction | 1.828 ** | 0.019 | 130 |
| Metal products for structure | 1.518 | 0.191 | 146 |
| Metal tanks and reservoirs for equipment | 1.331 | −0.012 | 125 |
| Metal cans, barrels, and drums | 1.616 | 0.146 | 128 |
| Handtools | 1.125 | −0.099 | 141 |
| Bolts, nuts, screws, rivets, and washers | 1.688 ** | −0.168 | 135 |
| Fabricated wire products | 1.485 | −0.426 ** | 144 |
| Fastening metal products | 1.661 ** | 0.038 | 133 |
| Treatment and coating of metals and Misc. fabricated metal products | 1.722 ** | −0.060 | 167 |
| Internal combustion engines and turbines | 1.649 *** | 0.063 | 152 |
| Parts of general-purposed machinery and equipment | 1.401 | 0.234 | 154 |
| Conveyors and conveying equipment | 1.649 ** | −0.110 | 161 |
| Air-conditioning equipment and industrial refrigeration equipment | 1.524 ** | 0.209 | 159 |
| Boiler, Heating apparatus and cooking appliances | 1.610 * | 0.274 ** | 160 |
| Pumps and compressors | 1.601 ** | −0.018 | 154 |
| Misc. machinery and equipment of general purpose | 1.441 | 0.146 | 171 |
| Metal cutting type machine tools | 1.201 | −0.419 | 157 |
| Metal forming machine tools | 1.296 | −0.212 | 153 |
| Agricultural implements and machinery | 1.620 *** | 0.129 | 151 |
| Construction and mining machinery | 1.577 ** | 0.025 | 152 |
| Food processing machinery | 1.592 ** | 0.278 *** | 139 |
| Textile machinery | 1.468 * | 0.199 | 161 |
| Metal molds and industrial patterns | 1.662 ** | 0.169 | 148 |
| Misc. machinery and equipment of special purpose | 0.745 | 0.348 | 178 |
| Motors and generators | 1.731 *** | 0.187 ** | 157 |
| Electric transformers | 1.851 *** | 0.087 | 146 |
| Capacitors and rectifiers, Electric transmission and distribution equipment | 1.583 *** | −0.005 | 163 |
| Insulated wires and cables | 1.777 *** | −0.089 | 165 |
| Batteries | 1.404 | 0.275 | 147 |
| Electric lamps and electric lighting fixtures | 1.575 ** | −0.068 | 156 |
| Misc. electric equipment and supplies | 1.503 * | 0.082 | 151 |
| Electron tubes | 1.709 *** | 0.393 ** | 155 |
| Digital display | 1.090 | 0.693 | 155 |
| Semiconductor devices | 1.542 ** | 0.371 | 158 |
| Integrated circuits | 1.181 | 0.331 | 163 |
| Electric resistors and storage batteries | 2.033 *** | 0.582 *** | 152 |
| Electric coils, transformers | 1.348 | 0.439 *** | 138 |
| Printed circuit boards | 1.550 ** | 0.357 * | 156 |
| Misc. electronic components | 1.416 | 0.499 * | 166 |
| Television | 1.448 | 0.865 ** | 146 |
| Electric household audio equipment | 2.141 *** | 0.564 *** | 147 |
| Other audio and visual equipment | 1.614 * | 0.402 * | 160 |
| Line telecommunication apparatuses | 1.636 ** | 0.118 | 157 |
| Wireless telecommunication and broadcasting apparatuses | 1.485 | 0.933 | 159 |
| Computer and peripheral equipment | 1.660 ** | 0.619 * | 162 |
| Office machines and devices | 1.536 * | 0.332 ** | 150 |
| Household refrigerators | 1.795 *** | 0.213 *** | 148 |
| Household laundry equipment | 1.480 ** | 0.399 *** | 141 |
| Other household electrical appliances | 1.436 | 0.057 | 156 |
| Medical instruments and supplies | 1.793 *** | 0.271 ** | 163 |
| Regulators and Measuring and analytical instruments | 1.603 ** | 0.266 ** | 163 |
| Photographic and optical instruments | 2.116 *** | 0.688 *** | 161 |
| Watches and clocks | 1.615 ** | 0.618 *** | 143 |
| Passenger automobiles | 1.674 *** | 0.334 *** | 151 |
| Buses and vans | 1.736 *** | 0.208 *** | 148 |
| Trucks and Motor vehicles with special equipment | 1.845 *** | 0.229 *** | 150 |
| Motor vehicle engines, chassis, bodies and parts | 1.235 | 0.302 | 184 |
| Trailers and containers | 1.391 | 0.407 ** | 131 |
| Steel ships | 1.549 ** | −0.203 | 177 |
| Other ships | 1.888 *** | −0.287 *** | 162 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Ship repairing and ship parts | 1.799 *** | 0.154 ** | 147 |
| Railroad vehicles and parts | 1.537 ** | 0.174 | 153 |
| Aircraft and parts | 1.283 | −0.043 | 155 |
| Motorcycles and parts | 1.687 ** | 0.095 | 144 |
| Bicycles and parts and misc. transportation equipment | 1.860 *** | 0.400 *** | 128 |
| Wood furniture | 1.495 * | 0.447 *** | 161 |
| Metal furniture | 1.565 ** | 0.006 | 142 |
| Other furniture | 1.090 | −0.221 | 162 |
| Toys and games | 1.189 | −0.038 | 157 |
| Sporting and athletic goods | 1.720 * | −0.058 | 155 |
| Musical instruments | 1.506 ** | −0.005 | 151 |
| Pens, pencils, and other artists' materials | 1.794 *** | 0.160 * | 141 |
| Jewelry and plated ware | 1.524 | 0.456 ** | 120 |
| Misc. manufacturing products | 1.448 | 0.131 | 192 |
| Hydroelectric power generation | 1.447 | 0.371 * | 109 |
| Fire power generation | 0.944 | −3.262 * | 119 |
| Nuclear power generation | 0.901 | 5.375 *** | 122 |
| Other generation | 1.491 | 0.378 | 94 |
| Manufactured gas supply | 1.142 | 5.584 *** | 109 |
| Steam and hot water supply | 1.472 | 0.413 *** | 101 |
| Water supply | 1.675 ** | 0.285 ** | 120 |
| Residential building construction | 0.964 | −3.307 ** | 174 |
| Non-residential building construction | 1.169 | −0.187 | 178 |
| Building repairs | 1.123 | 0.316 | 164 |
| Road construction | 1.389 * | 0.023 | 175 |
| Railroad construction | 1.432 * | −0.045 | 166 |
| Breakwater, pier, and harbor construction | 1.122 | −0.061 | 156 |
| Airport construction | 1.212 | −0.177 | 154 |
| Dam, levee, and flood control project construction | 1.371 | 0.172 | 158 |
| Water main line and drainage project construction | 1.306 | −0.018 | 165 |
| Land clearing and reclamation, and irrigation project construction | 1.539 ** | 0.009 | 163 |
| Land leveling and athletic field construction | 1.348 | −0.101 | 169 |
| Electric power plant construction | 1.334 * | −0.125 | 167 |
| Communications line construction | 1.585 ** | 0.006 | 155 |
| Misc. construction | 1.111 | −3.552 *** | 170 |
| Wholesale and Retail trade | 0.879 | 1.296 * | 145 |
| Restaurants | 1.131 | 0.719 | 177 |
| Accommodation | 1.657 ** | 0.094 | 128 |
| Railroad passenger transport | 2.544 *** | −0.181 * | 131 |
| Railroad freight transport | 1.452 | 0.602 *** | 117 |
| Road passenger transport | 1.983 *** | 0.285 ** | 127 |
| Road freight transport | 1.961 ** | 0.370 *** | 127 |
| Coastal and inland water transport | 1.552 ** | 0.265 *** | 130 |
| Oceangoing transport | 1.439 | 1.656 *** | 136 |
| Air transport | 1.458 | 0.681 *** | 153 |
| Supporting land transport activities | 1.555 ** | 0.507 *** | 122 |
| Supporting water transport activities | 1.637 ** | 0.029 | 121 |
| Supporting air transport activities | 2.164 *** | 0.339 *** | 104 |
| Cargo handling | 1.861 ** | −0.373 *** | 118 |
| Warehousing and storage | 1.529 | −0.133 | 126 |
| Other services incidental to transportation | 1.407 | −0.540 ** | 117 |
| Postal services | 1.444 | −1.093 *** | 112 |
| Telecommunications | 1.623 * | −0.213 | 119 |
| Broadcasting | 0.983 | −5.878 | 119 |
| Central bank and banking institutions, Non-bank depository institutions | 1.864 ** | 0.287 *** | 116 |
| Other financial brokerage institutions | 1.663 | 0.401 *** | 104 |
| Life insurance | 1.627 * | −0.005 | 102 |
| Non-life insurance | 1.586 * | 0.250 * | 103 |
| Services auxiliary to finance and insurance | 1.585 | 0.000 | 105 |
| Owner-occupied housing | −3.798 | 0.119 | 5 |
| Renting and subdividing of real estate | 1.557 | −0.235 * | 119 |
| Services related to real estate | 2.091 ** | −0.080 | 87 |

Continued.

| sector | Elasticity | TFPg | Obs. |
|---|---|---|---|
| Research institutes(public) | 1.611 ** | −0.080 | 178 |
| Research institutes(private, non-profit, commercial) | 1.498 * | 0.566 *** | 148 |
| Research and experiment in enterprise | 1.415 ** | −0.502 *** | 221 |
| Legal and accounting services | 1.355 | 0.152 | 83 |
| Market research and management consultancy | 1.339 | 0.225 | 91 |
| Advertising services | 1.109 | 4.591 *** | 121 |
| Architectural engineering services | 1.606 ** | −0.048 | 139 |
| Computer softwares development and supply | 1.299 | 0.197 | 111 |
| Computer related services | 1.310 | 1.045 *** | 107 |
| Renting of machinery and goods | 1.355 | −0.678 *** | 129 |
| Cleaning and disinfection services | 1.552 * | 0.058 | 100 |
| Misc. business services | 1.337 | −0.619 ** | 125 |
| Public government | 0.432 | −0.647 *** | 201 |
| Local government | 1.223 | 1.315 ** | 210 |
| Education (public) | 1.936 *** | −0.231 ** | 165 |
| Education (private, non-profit) | 1.525 * | −0.509 *** | 144 |
| Education (commercial) | 1.682 ** | 0.417 *** | 123 |
| Medical and health services(public) | 2.180 *** | −0.011 | 134 |
| Medical and health services(Private, non-profit) | 1.946 *** | −0.046 | 137 |
| Medical and health services (commercial) | 2.288 *** | 0.030 | 156 |
| Social work activities(public) | 2.169 *** | 0.124 | 117 |
| Social work activities(other) | 1.757 ** | 0.229 ** | 133 |
| Sanitary services(public) | 1.701 ** | 0.185 | 126 |
| Sanitary services(commercial) | 1.398 | 0.056 | 125 |
| Newspapers | 1.873 *** | −0.049 | 114 |
| Publishing | 1.473 * | 0.154 | 120 |
| Library, museum and similar recreation related services(public) | 1.843 *** | 0.112 | 129 |
| Library, museum and similar recreation related services(other) | 1.578 * | 0.066 | 131 |
| Motion picture, Theatrical producers, bands, and entertainers | 1.619 *** | 0.158 * | 147 |
| Sports organizations and sports facility operation | 1.635 *** | 0.241 ** | 140 |
| Misc. amusement and recreation services | 1.817 *** | 0.514 *** | 149 |
| Business and professional organizations | 2.735 *** | 0.335 *** | 91 |
| Other membership organizations | 1.855 ** | 0.225 ** | 110 |
| Motor repair services | 1.339 | 0.440 *** | 140 |
| Other personal repair services | 1.925 *** | −0.225 *** | 143 |
| Laundry and cleaning services | 1.585 | 0.336 ** | 87 |
| Barber and beauty shops | 1.559 | −0.028 | 89 |
| Personal services | 1.977 *** | −0.110 * | 120 |
| Office supplies | | | |
| Business consumption expenditures | | | |
| Nonclassifiable activities | | | |