A comparison of Productivity Level among China, Japan, ROK and USA using international input-output tables

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1. Introduction

Productivity is commonly defined as the ratio of output to inputs used in the production process. In other words, it measures how efficiently production inputs, such as labor and capital, are being used to produce a given level of output in an economy. Productivity is considered a key source of economic growth and competitiveness and, as such, is basic statistical information for many international comparisons and country performance assessments.[1] This definition can represent a manufacturer's productivity or an indicator of the overall economic efficiency level in the macroeconomics. Productivity is usually measured

[1] Paul Krugman, The Age of Diminishing Expectations (1994), "DEFINING AND MEASURING RODUCTIVITY" https://www.oecd.org/sdd/productivity-stats/40526851.pdf

by total factor productivity (TFP), which was first proposed by Solow (1957). TFP is on the basis of neoclassical economics, and the production function method developed on the basis of Solow's residual value became the mainstream method of total factor productivity measurement. The current measurement of total factor productivity is based on the theory of neoclassical economics and is based on the premise of perfect competition, minimum production cost and maximum profit.

According to the neoclassical economic theory, the concept of capital is the productive capacity of capital, and labor is the utility of labor. Therefore, the input of capital and labor is defined as the input of labor service and capital service. Dai and Izumi (2014) pointed out that when the capital and labor are measured by service quantity, the output and input change simultaneously, so the productivity is usually constant. Therefore, the TFP growth underestimates the productivity growth.

The concept of Total Labor was first proposed by Okishio (1954), and Izumi (1992) calculated the total labor productivity (TLP) under the framework of input and output tables. According to the total labor model, all the inputs can convert into single-type labor without any assumptions, and all types of inputs can be aggregated directly. The total labor productivity can be measured under any economic system excluding price affected, and is not restricted by various economic systems.

In recent years, there has been some progress in the study of the measurement of total labor productivity, but all the existing measurements are based on the national input-output table which can be used only on the assumption that the input labor of one unit of imported raw material and equipment is consistent with that of producing one unit of export goods. However, when using the international input-output table to measure the total labor, we can calculate the labor of imported products directly without any assumption. The results are not affected by the factors such as exchange rate, and closer to actual productivity. In this paper, firstly we elaborate the differences between TLP and TFP, and argue that TLP can be calculated more accurately by international I-O table. Secondly, we calculate the TLP by national I-O table and international I-O table respectively and compare their results. Thirdly, we show the results of comparisons of productivity level by industry among China, Japan, South Korea and the United States.

2. The difference between TLP and TFP

Although total labor productivity (TLP) and total factor productivity (TFP) are both defined as the ratios of output to input, they were constructed under different theoretical frameworks. The total labor productivity is based on the labor theory of value of Marx's economics and is defined under the framework of input-output analysis, while the total factor productivity proposed by Solow (1957) and later Jorgenson et al. (1967) is based on neoclassical economic theory and has nothing to do with the input-output framework. As TFP and TLP are based on different theoretical foundations, they express input and output in completely different ways. The following briefly discusses the differences in the concept of input and output between TFP and TLP.

First, we compare the definition of the input between TFP and TLP. The definition of input in TFP is the input service which is based on the definition of neoclassical economics: it is measured as the total of inputs capital service and labor service. In the neoclassical economic theory, it is assumed that the producers all aim at maximizing profits, and select the optimal combination of inputs to minimize input cost and maximize output. When producers choose the optimal input combination, the input cost is measured by the input factor service. In a sense, the input defined as the service is a concept consistent with the neoclassical economics producer selection theory, but for measuring productivity, there are big defects. The TFP growth rate is often mistaken for a comprehensive indicator of productivity changes caused by improvements in the performance of all production factors, and in fact the performance improvement of the production factors themselves is not included in the measurement of TFP growth rates.[2] The main reason for the TFP growth rate that does not include productivity improvement which comes from capital performance improvement and labor skill improvement is that TFP defines input factors as the service quantity of production factors. When the introduction of foreign advanced equipment for production, due to the upgrading of equipment, that is, the performance of fixed capital is improved, an increase in output will be the result, but at the same time the service provided by the equipment (capital) as the input increases.[3] Similarly, when labor skills improve from primary workers to skilled workers, output increases while the amount of services provided by labor increases.[4] The growth rate of the TFP is not measured by the increase in productivity caused by factors of production. For example, changes in production management methods have an impact on output, and changes in production management methods are not production factors. It measures the increase in productivity caused by other factors that have an impact on output. If the input factors measured by TFP are not only fixed capital and labor, but also the input of raw materials, fuel, and production management methods are all using factor services as the measurement indicators, there will inevitably be an increase in both inputs and outputs, if all the factors that affect the output are taken into account, the change of all production factors' services and the change of output must be equal, and the TFP growth rate must be zero.[5] (Torii, 1979; Jorgenson et al., 1967)

The existing TFP calculation results do not include the increase in productivity brought about by equipment upgrades and labor skill improvement, and is a defective indicator. Therefore, we need an indicator of productivity growth that can measure the technological advancement of all factors of production. Total labor productivity is the ratio of input to output of total labor (including direct and indirect labor[6]). It

[2] The OECD (2001) productivity projection manual clearly states that the TFP growth rate estimated using the current projection method does not include improvements in equipment and worker skills.

[3] Usually the accounting of capital investment is calculated at the rental price of the equipment. When equipment is replaced, the increase in rental prices means an increase in the input of capital.

[4] Usually the labor input is calculated on the basis of labor wages. When workers change from primary workers to skilled workers, wages rise, which means that labor input increases.

[5] Torii Hirohiko (1979) "Economic Development Theory" pointed out that if capital investment is measured by service, the final technology investment becomes an increase in the input of capital , and technological progress is not reflected in productivity increase, and capital productivity is usually constant. Jorgenson D.W., Griliches Z. (1967) "The explanation of Productivity change" indicates that TFP should be zero if there is no error in accurately measuring the input of service. The current TFP is not 0, which is actually a computational error.

[6] Direct labor refers to the labor input required for production in various industries; indirect labor refers to the labor required to produce raw materials, equipment, and factories.

is different from single factor labor productivity. It is a measure of multi-factor productivity and is an indicator similar to total factor productivity. The input in total labor productivity is not the concept of service, but the sum of the necessary labor time required for direct labor and indirect labor of production capital and raw materials. The input of TLP is the physical quantity of human beings. When the skill of laborers is improved, the physical quantity of direct labor invested has not changed. When the technology of fixed capital is improved, the physical quantity of indirect labor has not changed, but the output has increased, and TLP is raised. [7] Compared with TFP, TLP includes the increase in productivity brought about by the improvement of the quality of various production factors, and is a comprehensive indicator that more fully reflects changes in productivity growth. Capital input uses the product of the depreciation of fixed capital and the input of fixed capital. The depreciation of fixed capital is the stock of fixed capital (the labor required to convert to production capital) divided by the year of use. Such calculation methods will not increase the input of equipment renewal. Labor input adopts the quantity of human beings. No matter how the labor skill changes, if the number of people does not change, the input will not change. Therefore, the labor input will not increase with the improvement of labor skills.

Secondly, TFP and TLP use different methods for summing inputs. In most TFP calculations, TFP is defined as the change in the production function, ie. the change in the coefficient of the production function. The production function is the relationship between the production factor and the maximum output allowed by the technology. When estimating the TFP, it is necessary to determine which production function is to be used, and to assume that the technology (TFP) will change when the coefficient of the production function changes. However, changes in technology (TFP) and mutual replacement between factors in the same technology may lead to changes in the coefficients of the production function, while neoclassical economics interprets all coefficient changes as the result of technological changes, failing to distinguish between coefficient changes that occur when the factors are replaced. When we calculate the production function, we not only need data such as output, labor services, and capital services, but also need to be under the assumption that in complete competition, minimum production cost or maximum production, and production elasticity (output change/production factor input change) are equal with production factors. Whether or not such an assumption is true in the real economy determines the size of the deviation in the estimation method.

TLP converts various inputs of different nature into no different abstract human labor hours. Labor is the consumption of mental and physical strength, is homogeneous, and can be directly added without any assumptions. Specifically, fixed capital and raw materials are the result of labor. It can measure the labor time required to produce fixed capital and raw materials, that is, convert the capital and raw materials into

[7] Capital input uses the product of the depreciation of fixed capital and the input of fixed capital. The depreciation of fixed capital is the stock of fixed capital (the labor required to convert to production capital) divided by the year of use. Such calculation methods will not increase the input of equipment renewal. Labor input adopts the quantity of human beings. No matter how the labor skill changes, if the number of people does not change, the input will not change. Therefore, the labor input will not increase for the improvement of labor skills.

the labor time that needed in the production through input-output models. The total input of the TLP is the total of the direct labor time and the indirect labor time.

The input labor of this paper does not consider the difference of labor time, labor intensity and complexity between laborers in different industries. It is only measured in human years, and there is still much room for improvement in the future. Although the existing method of using the person-by-year units to measure input factors is slightly rough, the difference in labor time, intensity, and complexity among workers in different industries accounts for a very small proportion of inputs, even if these differences are ignored, the results of the calculation still have a certain significance in economic analysis.

3. The model of calculation

Okisio (1954) put forward the concept of total labor and proposed the following commodity value formula:

$$t_i = \sum_{j=1}^{k} a_{ij} t_j (i = 1, \ldots, k, k+1, \ldots, k+l) \quad (1)$$

Formula (1) shows there are k kinds of production materials and l kinds of consumption materials, a_{ij} means the input quantity of goods j required for producing goods i. t_i is the direct and indirect necessary labor time, and τ_i is the direct necessary labor time. Formula (1) shows that the value of a commodity is determined by direct and indirect labor. Using this formula, the commodity can be converted into the direct and indirect necessary labor time which is required for the production of the commodity.

3.1 Total labor model based on national input-output table

After the initial commodity value formula was proposed by Okisio (1954)，Quan (1984) and Yamada (1991) developed the formula and proposed the total labor model based on national input-output tables. Equation (2) is the total labor measurement model in a closed economy.

$$t_i = \sum_j (a_{ji} + k_{ji}) t_j + \tau_i \quad (2)$$

In expression（2）, t_i is total labor of one unit of product in the i industry (the sum of direct and indirect labor); a_{ji} is the intermediate raw material of the j department required for the production of one unit of the i-th industry; k_{ij} is the fixed capital consumption of the j department for one unit product of the i-th industry; τ_i is the direct labor required by the j department for one unit product of the *i-th* industry. This expression divides production factors into intermediate inputs, fixed capital inputs, and direct labor inputs. $(a_{ji} + k_{ji})t_j$ is the sum of $(t_j \cdot a_{ji})$ and $(t_j \cdot k_{ji})$, $\sum_j t_j a_{ji}$ is the labor of intermediate raw materials, $\sum_j t_j k_{ji}$ is the labor of capital, and together with direct labor τ_i becomes the total labor input required for one unit of output, called total labor. According to the definition of total labor，expression (2) can be expressed as:

$$t = \tau[I - A - k]^{-1} \quad (3)$$

The total labor measured by the formula（3）does not include the role of the imported input in the production. In the open economy, when the imports are used as intermediate inputs, the labor required for domestic production is determined not only by the input coefficient of domestic production, but also by the input coefficient of the imported goods. When calculating the data based on the national input-output table, it is impossible to find the input coefficient of the imported products, and we used the alternative methods to deal with the imported inputs.

Nagatani (1976) measured the labor input of various industries in Japan， Yamada et al. (2005) measured the total labor productivity of Japan and the United States, and Izumi et al. (2005) measured the growth rate of the total labor productivity in Japan and China. The above papers assume that the average labor required for one unit of export is equal to the labor required for one unit of imported goods, and the total labor t_i is obtained by the following formula:

$$t_i = \sum_{j=1}^{n}(a_{ji} + k_{ji})\, t_j + m_i \cdot t_m + \tau_i \quad (i = 1,2,\dots,n) \tag{4}$$

$$t_m = \sum_{i=1}^{n} e_i t_i \tag{5}$$

In expression (4), m_i is the imports which are required for the 1 unit of currency output of the *i* industry; t_m is the labor which required to obtain imports of 1 unit of currency; e_i is the ratio of exports of 1 unit of currency to the output of the *i* industry.

Substituting $t_i = t$; $a_{ji} = A$; $k_{ji} = K$; $m_i = m$; $\tau_i = \tau$; $e_i = \mathrm{e}$ in equations (4) and (5) can be rewritten as:

$$\mathrm{t} = [\mathrm{A} + \mathrm{K}]\mathrm{t} + \mathrm{m} \cdot t_m + \tau \tag{6}$$

$$t_m = et \tag{7}$$

From equations (6) and (7), we can get $\mathrm{t} = [\mathrm{A} + \mathrm{K}]\mathrm{t} + \mathrm{met} + \tau = [A + K + me]t + \tau$, therefore,

$$\mathrm{t} = [\mathrm{I} - \mathrm{A} - \mathrm{K} - \mathrm{me}]^{-1}\tau \tag{8}$$

The formula (8) is the basic model of the total labor based on the national input-output table. Since the model does not measure the actual labor of the imported products, but uses the average labor of the unit's domestic exports to replace, the result is not the actual total labor used in a certain industry, but rather the total labor based on the technology of the country.

3.2 Total labor productivity growth model based on national input-output table

The units in (3) and (8) are quantity, but the statistics are expressed in terms of amounts. Therefore, the t_i is the total labor contained in one unit of currency, and the total labor is not an indicator of productivity. Usually productivity indicators are $1/t_i$, not p_i/t_i. p_i/t_i is the amount of *i*-products that can be produced by labor per unit time, and *i*-products are still represented by price. Productivity should be determined by the level of technology and should not be related to price, but p_i/t_i leads to non-equivalent exchange due to different prices. When the input labor of one unit in *i*-th commodity exchanged by the ratio of p_i/t_i and if f $p_i/t_i < p_j/t_j$, the *i*-commodity input labor is at an unfavorable exchange rate compared to the *j*-th commodity input labor. Therefore, when measuring productivity growth, the price deflator can be used to convert the price p_i of the *i* industry into a fixed price, that is, the reciprocal of the total labor contained in the one unit of fixed price currency. The total labor productivity is:

$$\left[\frac{1}{t_1}\ \frac{1}{t_2}\ \cdots \frac{1}{t_n}\ \right] \tag{9}$$

Taking formula (9) as the natural logarithm and then differentiating it, you can get:

$$-dInt = \left[-\frac{dt_1}{t_1} \quad -\frac{dt_1}{t_1} \quad \cdots -\frac{dt_1}{t_1}\right] \tag{10}$$

Equation (10) is the expression the TLP growth rate. The TLP growth rate is the growth rate of the actual output of direct and indirect labor inputs of various sectors and reflects not only the change of direct labor input, but also the change of indirect labor such as intermediate materials and capital input.

4. Estimation of total labor quantity in China, Japan, Korea and the United States

The existing studies of total labor productivity, including Yamada et al. (2005), Izumi et al. (2005), Nagasawa (2009), Dai and Izumi (2014), measured the total labor based on the national input-output table. Since the import goods are produced by different countries, it is impossible to measure the labor input of import goods based on the national input-output table, therefore, it is necessary use the average labor of one unit of export to replace the labor of one unit of import. When the measurement is based on the world input-output table, the input labor of the import can be directly calculated without the above substitution. When we calculate TLP and TLP growth rate by the national input-output table, it will not have a large influence on the results even if the average labor substitution of exports is used, because the proportion of imports in the production of a country is not large. In order to see the difference between the results by the national input-output table and the world input-output table, two methods are used in this paper.

4.1 Data Sources

The currently published World Input-Output Table has the Eora MRIO as well as the WIOD compiled by the OECD. The Eora MRIO table includes 189 countries and regions. Although it does not cover all 224 countries and regions in the world, it still contains economic exchanges in most countries and regions of the world. The WIOD table only contains 40 countries and regions and cannot reflect most economic changes in the world. This paper uses the Eora MRIO table[8] as the basic table for measurement.

When measuring the growth rate of TLP, it is necessary to convert the prices in the Eora MRIO table into fixed price input-output table. Since the Eora MRIO table does not publish fixed price table, but OECD WIOD table not only publishes the current price list, but also publishes the price list of the previous year, we can calculate the price deflator for the TLP growth rate of each department.

In order to compare the difference in results of the TLP and TLP growth rates between the national input-output table and the world input-output table, when using the national input-output table for measurement, we used tables which from the Eora MRIO table, but not the national input-output table of China, Japan, Korea and the United States. In order to correspond to the department of the WIOD table we combined the

[8] Due to need to use the data of the WIOD table, the Eora MIRO and WIOD tables are combined into the 20-sector table of the same departmental classification for the measurement of the total labor and TLP growth rate.

Eora MRIO table from 26 sectors into 20 sectors and extracted the intermediate input part of the 4 countries, and then combined the exports into one row and one column.

In addition, we think the employment data of OECD WIOD is more accurate than the employment data of Eora MRIO, and matrix in the attached table of WIOD provides the data of the number of employees by each sector in each country for 40 countries and the data for the remaining 149 countries are provided by the attached table of Eora MRIO.

4.2 Measuring Model of Total Labor quantity

We use two methods to calculate total labor quantity. One method is the use of national input-output tables and another method is the use of the international input-output table.

4.2.1 The model of total labor quantity by using national input-output table

TLP is the direct and indirect labor which is required for 1 unit of output, so the estimation of total labor quantity is the base of TLP. In the real economy, raw materials and fixed capital are likely to use imported products. When we calculate total labor quantity by using national input-output tables, labor quantity inputted in imported goods is calculated by using average inputted labor quantity of exported goods, that is, assuming that the labor of imported intermediate products is produced domestically. The assumption is based on the thinking that in order to import goods, foreign currencies are necessary and in order to get foreign currencies, exporting goods is necessary. Therefore, the labor quantity which is required to import one unit of product can be replaced by the average labor quantity which is required to export one unit of product. If the average amount of labor required to produce an export product is taken as the amount of labor input in acquiring foreign currency, then the labor required to obtain foreign currency in the country is equivalent to the labor required to obtain the imported product. Based on this idea, most researchers use this method to deal with the labor required to import products.

According to the Eora MRIO table of 20 departments, the model includes 20 intermediate input sectors, 1 column of fixed capital formation, 1 row of fixed capital loss, 1 column of export, 1 row of import, and 22 rows and 22 columns of matrix. The model is as follows:

$$(\mathbf{t} \quad c \quad s) = (\mathbf{t} \quad c \quad s)\begin{pmatrix} \mathbf{A} & \mathbf{f} & \mathbf{e} \\ \mathbf{d} & 0 & 0 \\ \boldsymbol{m} & w & 0 \end{pmatrix} + (\boldsymbol{\ell} \quad 0 \quad 0) \qquad (11)$$

From expression (11), we can get expression (12),

$$(\mathbf{t} \quad c \quad s) = (\boldsymbol{\ell} \quad 0 \quad 0)\left\{\mathbf{I} - \begin{pmatrix} \mathbf{A} & \mathbf{f} & \mathbf{e} \\ \mathbf{d} & 0 & 0 \\ \boldsymbol{m} & w & 0 \end{pmatrix}\right\}^{-1} \qquad (12)$$

t= (t_j): total labor per one unit currency, row vector;

c: total labor per one unit currency of fixed capital, scalar;

s: total labor per one unit currency of exports (import), scalar;

$\mathbf{A} = (a_{ij})$: domestic product intermediate input coefficient, matrix;

$\mathbf{f} = (f_i)$: the ratio of fixed capital formation to domestic products, column vector;

$\mathbf{e} = (e_i)$: the proportion of exports, column vector;

$\mathbf{m} = (m_i)$: intermediate input coefficient of exports, column vector;

$\mathbf{d} = (d_i)$: capital consumption, row vector ;

W: the ratio of fixed capital formation to import products, scalar;

$\boldsymbol{\ell} = (\ell j)$: direct labor per one unit currency, row vector;

I: unit matrix;

0: zero (scalar).

4.2.2 The calculation of total labor quantity by using international input-output tables

When we calculate total labor quantity by using international input-output tables, labor quantity inputted in imported goods is calculated as labor quantity necessary for production of that goods in the country where they are produced.

Here we use the 20 sectors Eora MRIO table. Since each of the 189 countries has 20 endogenous sectors, one fixed capital formation and one fixed capital, and the rest of the world is one sector, so there are 3970 rows and 3970 columns (189×(20+1)+1 = 3970) .

As mentioned earlier, the direct labor coefficient (labor/output) for 40 countries is based on OECD WIOD data, and the remaining 149 countries use Eora MRIO data. The following is the formula that we used this time.

$$(\mathbf{t} \quad \mathbf{c}) = (\mathbf{t} \quad \mathbf{c})\begin{pmatrix} \mathbf{A} & \mathbf{F} \\ \mathbf{D} & \mathbf{0} \end{pmatrix} + (\boldsymbol{\ell} \quad 0) \tag{13}$$

From formula (13), we can get formula (14):

$$(\mathbf{t} \quad \mathrm{c}) = (\boldsymbol{\ell} \quad 0)\left\{\mathbf{I} - \begin{pmatrix} \mathbf{A} & \mathbf{F} \\ \mathbf{D} & 0 \end{pmatrix}\right\}^{-1} \tag{14}$$

$\mathbf{t} = (t^{\beta}_{j})$: Total labor quantity per one unit currency of j product in β country (row vector);

$\mathbf{c} = (c^{\beta})$: Total labor quantity per one unit currency of β country (row vector);

$\mathbf{A} = \left(a^{\alpha\beta}_{ij}\right)$; Input coefficient (α is input country, β is demand country, i is input industry, j is demand industry) (matrix);

F= $\left(f^{\alpha\beta}_{i}\right)$: Component ratio of fixed capital formation (matrix), α (row) is country producing fixed capital, $\beta(column) is$ country using fixed capital, i $(column)$ is kind of fixed capital

D= $(d^{\alpha\beta}_{j})$ Fixed capital consumption coefficient (matrix), α (row) is country inputting fixed capital into, β (column) is country consuming fixed capital, (Inserted 0 into cells where α *is* different from β), j is industry consuming fixed capital.

$\boldsymbol{\ell} = \left(\ell^{\beta}{}_{j}\right)$: Direct labor per one unit currency of j product in β country (row vector);

I: unit matrix;

0 : zero (matrix or row vector).

4.2.4 The calculation of total labor productivity growth

We calculate total labor productivity growths by using the total labor quantities. The calculation of productivity growth needs the data in constant price, and we use the previous years' prices table of WIOD to estimate the deflators and convert the total labor quantities from current prices to previous years' prices, and then calculate the productivity growths.

The following is the formula that we used to calculate total labor productivity growth.

$$G = \left(\frac{1}{T} - \frac{1}{P}\right) \Big/ \frac{1}{P} \tag{15}$$

G : Total labor productivity growth

T : This years' total labor quantity per one unit currency in previous years' price

P : Previous years' total labor quantity per one unit currency in previous years' price

5. The comparison of productivity among China, Japan, ROK and USA

According to the model introduced above, this paper measures the total labor of various industries in China, Japan, Korea and the United States, and compares the total labor productivity of various industries in the four countries, and measures the growth rate of the total labor productivity of each country.

5.1 The comparison of productivity level among China, Japan, ROK and USA

Table 1 is the result of the total labor productivity of various industries in China, Japan, Korea and the United States. From the results, we can deduct the following statements.

Firstly, the direct labor productivity in China is lower than that of the United States, Japan and South Korea. The number of people per currency goods using in China is 3.0 times that of Japan, 4.2 times that of South Korea, and 4.5 times that of the United States. That is to say, the direct labor productivity of the United States is the highest, South Korea’s is higher than Japan’s, and China’s is the lowest.

Secondly, China's total labor productivity by national or by the international input-output table is lower than that of the other three countries. The average TLP of South Korea is higher than Japan. The average TLP of the United States is the highest in the four countries.

Thirdly, we compared the productivity by industries in the four countries. ⑪ Construction, ⑫ Hotels and Restaurants, ⑬ Transport and ⑭ Post and Telecommunications are the relatively high productivity industries and the ⑥ Metal Products, ⑦ Electrical and Machinery, ⑧ Transport Equipment and ⑨ Other Manufacturing are the relatively low productivity industries. Japan's relatively high productivity are ⑫ Hotels and Restaurants, ⑭ Post and Telecommunications, ⑮ Financial Intermediation and Business Activities and the relatively low productivity ones are ⑦ Electrical and Machinery, ⑩ Electricity, Gas and Water, ⑬ Transport; South Korea's relatively high productivity lies in ②Fishing, ⑪ Construction, while the relatively low one lies in ① Agriculture, ③ Food & Beverages, ⑫ Hotels and Restaurants; The industry with relatively high productivity in the USA is ① Agriculture, ⑤ Petroleum, Chemical and Non-Metallic Mineral Products, ⑨ Other Manufacturing, and the industry with relatively low productivity is ⑪ Construction, ⑭ Post and Telecommunications.

Table1. Comparison of productivity level among China, Japan, ROK and USA

			①	②	③	④	⑤	⑥	⑦	⑧	⑨	⑩	⑪	⑫	⑬	⑭	⑮	⑯	⑰
CHN	Labor quantity (person year/ 10 million US, USA Price）	Direct Labor	1184	871	123	297	90	106	148	93	662	44	139	312	107	88	115	393	**259**
		Total Labor (national I-O table)	1695	1249	1693	1348	842	1107	1137	1329	1545	826	519	973	364	290	489	641	**812**
		Total Labor (international I-O table)	1498	1096	1087	930	378	471	518	586	1127	361	304	709	230	189	306	512	**528**
JPN	Labor quantity (person year/ 10 million US, USA Price）	Direct Labor	585	99	51	116	22	21	53	33	79	18	97	154	135	31	61	141	**87**
		Total Labor (national I-O table)	854	173	235	244	143	112	177	160	200	271	201	271	257	116	131	211	**183**
		Total Labor (international I-O table)	995	200	449	319	146	80	180	170	206	225	199	338	281	114	133	211	**199**
KOR	Labor quantity (person year/ 10 million US, USA Price）	Direct Labor	459	58	51	84	13	14	22	26	103	14	57	320	69	24	62	94	**61**
		Total Labor (national I-O table)	624	125	388	294	202	123	158	206	264	157	138	487	147	102	125	138	**166**
		Total Labor (international I-O table)	662	137	497	339	142	93	145	183	262	115	132	502	160	102	123	135	**159**
USA	Labor quantity (person year/ 10 million US$）	Direct Labor	46	130	19	58	10	29	30	19	46	14	72	154	50	23	40	98	**57**
		Total Labor (national I-O table)	103	174	93	121	60	91	75	80	96	47	115	198	96	70	81	137	**102**
		Total Labor (international I-O table)	120	181	147	147	77	80	81	90	114	59	125	212	99	72	86	142	**112**
CHN/JPN		Direct Labor	2.0	8.8	2.4	2.6	4.1	5.0	2.8	2.8	8.4	2.5	1.4	2.0	0.8	2.9	1.9	2.8	**3.0**
		Total Labor (national I-O table)	2.0	7.2	7.2	5.5	5.9	9.9	6.4	8.3	7.7	3.0	2.6	3.6	1.4	2.5	3.7	3.0	**4.4**
		Total Labor (international I-O table)	1.5	5.5	2.4	2.9	2.6	5.9	2.9	3.5	5.5	1.6	1.5	2.1	0.8	1.7	2.3	2.4	**2.6**
CHN/KOR		Direct Labor	2.6	15.0	2.4	3.6	6.8	7.7	6.7	3.5	6.4	3.1	2.4	1.0	1.6	3.7	1.9	4.2	**4.3**
		Total Labor (national I-O table)	2.7	10.0	4.4	4.6	4.2	9.0	7.2	6.4	5.9	5.3	3.8	2.0	2.5	2.8	3.9	4.6	**4.9**
		Total Labor (international I-O table)	2.3	8.0	2.2	2.7	2.7	5.1	3.6	3.2	4.3	3.1	2.3	1.4	1.4	1.9	2.5	3.8	**3.3**
CHN/USA		Direct Labor	25.7	6.7	6.3	5.1	8.8	3.7	5.0	5.0	14.4	3.2	1.9	2.0	2.1	3.8	2.8	4.0	**4.5**
		Total Labor (national I-O table)	16.5	7.2	18.2	11.2	14.0	12.1	15.2	16.7	16.1	17.7	4.5	4.9	3.8	4.1	6.0	4.7	**8.0**
		Total Labor (international I-O table)	12.4	6.1	7.4	6.3	4.9	5.9	6.4	6.5	9.9	6.1	2.4	3.3	2.3	2.6	3.6	3.6	**4.7**
JPN/KOR		Direct Labor	1.27	1.7	1	1.39	1.66	1.53	2.39	1.25	0.77	1.21	1.7	0.48	1.96	1.28	0.99	1.5	**1.43**
		Total Labor (national I-O table)	1.37	1.38	0.6	0.83	0.71	0.91	1.12	0.77	0.76	1.73	1.46	0.56	1.75	1.13	1.05	1.53	**1.1**
		Total Labor (international I-O table)	1.5	1.46	0.91	0.94	1.03	0.86	1.24	0.93	0.79	1.95	1.5	0.67	1.75	1.12	1.08	1.56	**1.26**
JPN/USA		Direct Labor	12.7	0.76	2.62	2.01	2.13	0.73	1.78	1.76	1.72	1.28	1.35	1	2.68	1.31	1.51	1.44	**1.51**
		Total Labor (national I-O table)	8.31	0.99	2.52	2.02	2.37	1.23	2.36	2	2.08	5.8	1.75	1.37	2.66	1.64	1.61	1.54	**1.8**
		Total Labor (international I-O table)	8.27	1.11	3.06	2.17	1.9	1	2.23	1.89	1.81	3.81	1.59	1.59	2.84	1.57	1.55	1.49	**1.78**
KOR/USA		Direct Labor	9.98	0.45	2.63	1.44	1.28	0.47	0.75	1.4	2.23	1.05	0.79	2.08	1.37	1.02	1.52	0.96	**1.06**
		Total Labor (national I-O table)	6.06	0.72	4.17	2.43	3.35	1.35	2.1	2.58	2.74	3.36	1.2	2.46	1.53	1.45	1.54	1.01	**1.63**
		Total Labor (international I-O table)	5.5	0.76	3.38	2.3	1.84	1.17	1.8	2.03	2.31	1.95	1.06	2.37	1.62	1.41	1.43	0.95	**1.42**

Note：

1. ① is Agriculture；② is Fishing；③ is Food & Beverages； ④ is Textiles and Wearing Apparel； ⑤ is Petroleum, Chemical and Non-Metallic Mineral Products; ⑥ is Metal Products; ⑦ is Electrical and Machinery; ⑧ is Transport Equipment; ⑨ is Other Manufacturing; ⑩ is Electricity, Gas and Water; ⑪ is Construction; ⑫ is Hotels and Restaurants; ⑬ is Transport; ⑭ is Post and Telecommunications; ⑮ is Financial Intermediation and Business Activities; ⑯ is Education, Health and Other Services; ⑰ is the average of all the industries (Fisher type with weight of labor quantity (direct labor or total labor by national I-O table or total labor by international I-O table)).

2. We cannot the compare the productivity of the Mining and Quarrying, Wood and Paper, Recycling, Maintenance and Repair, Wholesale Trade, Retail Trade, Public Administration and etc., because we didn't get the Purchasing power parity (PPP) of these departments.

3. Direct Labor=Total direct labor of net output / total net output value;

4. Total Labor (national I-O table)= Total labor of the net production by national I-O table / total net production value;

5. Total Labor (international I-O table)= Total labor of the net production by international I-O table / total net production value.

The difference in the total labor productivity by the national input-output table and the international input-output table is that when the productivity measured by the national input-output table, we use the average productivity of the export enterprise used to instead the productivity of the imported products. When the productivity is different from the exporting enterprises and the enterprises of importing country, the results of productivity by the national input-output table and by the international input-output table will be different. For example, the productivity of ⑤ Petroleum, Chemical and Non-Metallic Mineral Products, ⑥ Metal Products, ⑦ Electrical and Machinery, ⑧ Transport Equipment of China measured by national I-O table is more than twice as high as the international I-O table. From the average of industries in the four countries, the results of the productivity in China and South Korea measured by national I-O table is lower than that by the international I-O table, and it indicates that the productivity of Chinese and South Korean exporters is lower than that of imported producers. Meanwhile Japan and the United States derive a lower overall labor productivity from the international I-O table than the results derived from a national I-O table, indirectly indicating that Japanese and US exporters are more productive than import-producing countries.

5. 2 The comparison of productivity growth among China, Japan, ROK and USA

When using national I-O tables to measure the labor of the import intermediate products, it is necessary to assume that the domestic average labor of the exports is equal to the labor of the imports. When we measured the labor of imports by the international I-O table, we can measure the labor directly, without any assumptions. The difference of the productivity between the domestic exporting enterprises and the foreign countries of the imported goods leads to different results. This is because when we use the national I-O table for measurement, the proportion of imported products used by various departments in the production process (input coefficient) is much smaller than the proportion of domestic intermediate products and direct labor, and it is considered that when the average labor of exports replaces the imports, it does not have much impact on the result. However, comparing the results of the calculation, there is a big difference between the results of using the national I-O table and the international I-O table, and we can know that the previous guess is wrong. The reason of the difference between the two results is not only caused by the difference of the productivity between the domestic and the foreign countries, but also because the results contains direct and indirect effects, and the effect on the results is a multiplier, which ultimately leads to large differences between the two results. When we use the national I-O table to measure the productivity, the result is affected by the surrounding environment and exchange rate.

Table 2 shows the results of the full labor productivity growth rate of the four countries. From the results of Table 2, the following conclusions can be observed.

First, the growth rate of Chinese TLP is higher than that the other three countries, whether based on the national I-O table or the international I-O table. It can be shown that during the period of 2009-2014, China not only has a faster GDP growth, but also has a very high productivity growth. Chinese total labor growth rate measured by the international I-O table, is lower than the growth rate measured by China’s I-O table, indicating that China's domestic industry's productivity growth is higher than that of importing countries' productivity.

Second, South Korea’s TLP has grown rapidly. The TLP growth rate measured by the national I-O table has reached 5.9, higher than Japan (-1) and the United States (-0.2), and the TLP measured by the international I-O Table is 2.6, still higher than Japan (-1.9) and the United States (-2.3).

Third, the TLP growth rate measured by the international I-O table is lower than the growth rate measured by the national I-O table in the four countries, indicating that the growth rate of export enterprises in the four countries is higher than that of the importing countries.

It may be that the productivity of Korean domestic enterprises is higher than that of imported enterprises. The level of productivity growth may also be caused by fluctuations in the exchange rate of KRW.

China's total labor growth rate, measured by the World Input-Output Table, is lower than the growth rate measured by China's input-output table, indicating that China's domestic industry's productivity growth is higher than that of importing countries' productivity.

Table2. Comparison of productivity growth among China, Japan, ROK and USA

Sector			1	2	3	4	5	6	7	8	9	10	11
C	2009	Direct Labor Productivity Growth	11.5	11.2	5.2	10.6	11.4	9.0	11.0	8.6	12.9	9.1	10.1
H	↓	TLP Growth (national I-O table)	9.4	9.7	7.7	13.7	11.5	11.3	9.1	8.0	10.4	10.2	10.3
N	2014	TLP Growth (international I-O table)	9.5	9.6	7.1	13.5	10.9	10.8	8.3	7.4	9.1	8.9	10.0
J	2009	Direct Labor Productivity Growth	-0.5	-0.4	-3.5	-2.3	-4.4	-1.8	1.44	3.86	3.49	1.91	0.55
P	↓	TLP Growth (national I-O table)	-0.1	-0.7	-4	-0.8	-3.8	-0.7	-0	1.14	2.68	0.04	-0.2
N	2014	TLP Growth (international I-O table)	-0.2	-1.1	-0.8	-0.8	-3.6	-1.2	0.14	0.64	1.22	-2	-1.4
K	2009	Direct Labor Productivity Growth	7.7	5.7	4.7	7.5	9.1	-1.8	6.9	5.0	8.6	3.2	15.5
O	↓	TLP Growth (national I-O table)	7.4	5.8	-0.5	6.6	5.8	1.5	1.4	4.5	10.6	5.2	7.9
R	2014	TLP Growth (international I-O table)	5.9	3.8	-4.0	4.5	3.0	1.6	-1.1	0.4	6.1	1.2	4.0
U	2009	Direct Labor Productivity Growth	0.95	-0.9	2.55	-0.1	8.83	2.71	0.71	3.87	3.85	6.58	1.73
S	↓	TLP Growth (national I-O table)	-0.7	-0.5	-4.5	-2.9	2.44	0.36	-4.5	0.29	1.57	1.79	-0.2
A	2014	TLP Growth (international I-O table)	-3.5	-2	-7.5	-5	-0.7	-2.2	-6.8	-2.3	-1.4	-1.9	-2

			12	13	14	15	16	17	18	19	20	21	AVG
C	2009	Direct Labor Productivity Growth	18.4	18.2	7.0	6.1	8.9	6.9	5.5	3.9	2.9	5.7	**8.7**
H	↓	TLP Growth (national I-O table)	10.5	11.9	7.2	5.6	10.0	7.6	6.6	5.5	3.6	5.1	**8.4**
N	2014	TLP Growth (international I-O table)	9.7	11.4	6.5	5.4	9.7	7.0	5.9	5.0	3.2	4.8	**7.9**
J	2009	Direct Labor Productivity Growth	-5.5	-0.8	1.88	-0.7	-0.8	0.66	0.76	-1.8	-1	-2.6	**-0.3**
P	↓	TLP Growth (national I-O table)	-5.5	-3.6	-0.4	-0.7	-0.8	0.18	0	-1.6	-1.4	-2.3	**-1**
N	2014	TLP Growth (international I-O table)	-6.6	-1.7	-1.4	-1.9	-0.9	-0.7	-1.5	-3	-4.1	-3.4	**-1.9**
K	2009	Direct Labor Productivity Growth	15.4	15.0	0.0	6.7	4.5	4.5	13.4	2.5	3.4	3.2	**5.0**
O	↓	TLP Growth (national I-O table)	1.8	2.4	1.5	6.2	4.7	4.4	7.8	3.0	3.7	3.7	**5.1**
R	2014	TLP Growth (international I-O table)	-1.3	-1.8	-0.9	4.6	3.6	3.0	4.5	0.7	2.0	2.0	**2.6**
U	2009	Direct Labor Productivity Growth	-0.2	0.03	-0	3.68	0.51	2.21	3.9	0.76	-0.6	0.57	**1.63**
S	↓	TLP Growth (national I-O table)	-1.2	0.04	-0.4	0.55	0.02	-0.2	-0.7	-0.6	-1.3	-0.3	**-0.2**
A	2014	TLP Growth (international I-O table)	-0.7	-3	-2.3	-1.3	-1.2	-2.8	-3.6	-2.4	-3.6	-1.6	**-2.3**

Note: NO.1-21 is the industry. 1 is Agriculture；2 is Fishing；3 is Mining and Quarrying; 4 is Food & Beverages；5 is Textiles and Wearing Apparel； 6 is Wood and Paper; 7 is Petroleum, Chemical and Non-Metallic Mineral Products; 8 is Metal Products; 7 is Electrical and Machinery; 8 is Metal Products; 9 is Electrical and Machinery; 10 is Transport Equipment; 11 is Other Manufacturing; 12 is Recycling; 13 is Electricity, Gas and Water; 14 is Construction; 15 is Wholesale and Retail Trade, Maintenance, Repair; 16 is Hotels and Restaurants; 17 is Transport; 18 is Post and Telecommunications; 19 is Financial Intermediation and Business Activities; 20 is Education, Health and Other Services; 21 is Education, Health and Others.

5. Conclusion

From the above, it can be seen that there are great differences in the results by using the national I-O table and by the international I-O table. The following conclusions can be drawn from the above differences.

First, because of the current open economy, production in all countries of the world is interdependent.

In the production of a country, the raw materials, fuels, and machinery of the products may come from different countries. The production links may be located in different countries, and production is often completed on the basis of division of labor and cooperation on a worldwide scale. Based on this status quo, the international I-O table is more able to fully reflect the productivity indicators of production conditions.

Second, because the total labor of the imported goods is based on the market exchange rate the TLP will be changed due to the change of the exchange rate when measured by the national I-O table. From this perspective, the TLP based on the International I-O table is a better indicator, does not have similar problems.

Third, according to the international I-O table, the TLP is the productivity of an industry, including the final stage of the product and the intermediate production of the industry. Therefore, the productivity classified in a certain country is not very appropriate. From the perspective of measuring productivity of the country, the national I-O table is more suitable.

Direct labor productivity, the total labor productivity measured by national I-O table and by the international I-O table represent different meanings. Therefore, combining the data measured by the three method can provide a more comprehensive understanding of the productivity of each country, and can be applied to multi-angle analysis studies.

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