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Abstract

The study group on the Creation of a Productivity Database on Japanese, Chinese, and South Korean Firms at the Japan Center for Economic Research (JCER), in conjunction with the Center for Economic Institutions (CEI) of Hitotsubashi University, the Center for China and Asian Studies (CCAS) of Nippon University, and the Center for Corporate Competitiveness of Seoul National University, has compiled the East Asian Listed Companies Database 2007 (EALC 2007). In this paper, we explain the methodology and data sources used in the construction of the EALC 2007. We also conduct some descriptive analysis based on the EALC 2007.

To compare the TFP level of firms in these countries, we first estimated the TFP of firms in each country using the method of Good, Nadiri and Sickles (1997). Then we estimated the relative TFP by industry in the benchmark year using Japanese industries as benchmarks and combined the estimated TFP of firms. When estimating relative TFP by industry for Korea and China, we applied the industry-level price estimates of the three countries from the ICPA project and converted industry outputs and inputs into the same currency unit (Japanese Yen). The estimation results obtained indicate that the productivity of Japanese firms is still higher than that of their Chinese and Korean counterparts but that the productivity of Korean firms is rapidly increasing, with the emergence of some firms that are now overtaking their Japanese rivals in terms of productivity, particularly in the electric machinery sector.

JEL Classification: D24

Key words: Total Factor Productivity; International Comparison; Competitiveness

1. Introduction

In Japan, South Korea, China and other East Asian countries, the expansion of foreign direct investment and the growth of China's economy have created a rapid increase of international trade and the division of labor. South Korean firms such as Samsung Electronics and Hyundai Motor are now rapidly catching up with Japanese manufacturing firms. Meanwhile, through the conclusion of negotiations on a US-South Korea Free Trade Agreement (FTA), the potential conclusion of the ongoing negotiations on a Japan-South Korea FTA, and China's fulfillment of her World Trade Organization commitments, liberalization of the Chinese and South Korean markets will continue. Against this background, the question of which industries and what type of firms will be able to thrive following such liberalization is becoming a hot topic in these two countries. Although how far South Korean and Chinese firms have caught up with Japanese firms is an important question, very little research has been done on this topic.

Being aware of these issues, the study group on the Creation of a Productivity Database on Japanese, Chinese, and South Korean Firms at the Japan Center for Economic Research (JCER), in conjunction with the Center for Economic Institutions (CEI) of Hitotsubashi University, the Center for China and Asian Studies (CCAS) of Nippon University, and the Center for Corporate Competitiveness of Seoul National University, has compiled the East Asian Listed Companies Database 2007 (EALC 2007).[1] The EALC 2007, in principle, targets all listed firms (except firms in the financial sector) in Japan, China, and South Korea. It includes data necessary to measure total factor productivity at the firm level and the periods covered are 1985 through 2004 for Japanese firms, 1985 through 2005 for South Korean firms, and 1999 through 2004 for Chinese firms. Our study group developed our own method for the international comparison of firm level TFP. To the best of our knowledge, this is the first study to conduct an international comparison of the level of TFP using individual firm data.

For the EALC 2007, we mainly used publicly available financial data on Japanese, Chinese and South Korean listed firms. But in order to conduct this international comparison, we need to convert the output and inputs of firms in each country to a common currency with currency conversion factors (PPPs) which take cross-country differences in relative price levels into account. However, in contrast to the case of final expenditure prices, few estimates of PPPs for industry level output are readily available for developing countries. Fortunately, we have been able to obtain industry-level output PPP estimates for Japan, Korea and China to conduct a productivity

[1] The EALC 2007 is downloadable from the following JCER webpage: http://www.jcer.or.jp/eng/research/database070528.html.

comparison between these three countries thanks to the recently finished International Comparison of Productivity Among Asian Countries (ICPA) project.[2]

In this paper, we explain the methodology and data sources used in the construction of the EALC 2007. We also conduct some descriptive analysis based on the EALC 2007.

The remainder of this paper is organized as follows. The next section explains the estimation method used for the international comparison of firm-level TFP in Japan, Korea and China. One caveat with regard to our database is that it covers only listed firms. Especially in developing economies such as China, listed firms may have very different characteristics from ordinary unlisted firms, and their activities cover a relatively small part of the whole economy. In Section 3, to assess the seriousness of this problem in our database, we study the characteristics, and provide a brief history, of the stock market in each country. In order to provide an illustration of recent trends in the catch-up of South Korean and Chinese firms, in Section 4, focusing on the chemical/ pharmaceutical, primary metal, electric machinery and automobile industries, we present two or three representative firms in each industry from each of the three countries and compare their TFP levels,. Section 5 concludes.

2. Comparing Firm-Level TFP in Japan, South Korea and China: Methodological Issues

2.1. Estimation of Firm-Level TFP in Japan, South Korea and China

As a first step, we estimated each firm's TFP level relative to the industry average TFP level in its country. We used the Multilateral TFP Index method developed by Good, Nadiri and Sickles (1997).[3] The adoption of this method makes possible not only cross-sectional comparisons but also time-series comparisons of firm-level TFP. Suppose that the data cover a period from t=0 to T and t=t_0 (0<t_0<T) is the benchmark year. In this method, the TFP level of firm f in industry j of country m in year t, $TFP_{f,t,j,m}$ is calculated by

$$\ln TFP_{f,t,j,m} = (\ln Q_{f,t,j,m} - \overline{\ln Q_{t,j,m}}) - \sum_{i=1}^{n} \frac{1}{2}(S_{f,i,t,j,m} + \overline{S_{i,t,j,m}})(\ln X_{f,i,t,j,m} - \overline{\ln X_{i,t,j,m}}) \tag{1}$$

for t=t_0, and

[2] This project has been carried out by the Research Institute of Economy, Trade and Industry (RIETI) jointly with the International Comparison of Outputs and Productivity (ICOP) project of Groningen University as well as researchers from South Korea, Taiwan and China.

[3] Good, Nadiri and Sickles (1997) use an equation that accounts for changes in the composition of items for sale due to business diversification, but we conducted the TFP estimation on the assumption that firms produce only manufactured goods of the industry to which they belong.

$$\ln TFP_{f,t,j,m} = \left(\ln Q_{f,t,j,m} - \overline{\ln Q_{t,j,m}}\right) - \sum_{i=1}^{n} \frac{1}{2}\left(S_{f,i,t,j,m} + \overline{S_{i,t,j,m}}\right)\left(\ln X_{f,i,t,j,m} - \overline{\ln X_{i,t,j,m}}\right)$$
$$+ \sum_{s=t_0+1}^{t}\left(\overline{\ln Q_{s,j,m}} - \overline{\ln Q_{s-1,j,m}}\right) - \sum_{s=t_0+1}^{t}\sum_{i=1}^{n} \frac{1}{2}\left(\overline{S_{i,s,j,m}} + \overline{S_{i,s-1,j,m}}\right)\left(\overline{\ln X_{i,s,j,m}} - \overline{\ln X_{i,s-1,j,m}}\right) \quad (2)$$

for $t>t_0$, and

$$\ln TFP_{f,t,j,m} = \left(\ln Q_{f,t,j,m} - \overline{\ln Q_{t,j,m}}\right) - \sum_{i=1}^{n} \frac{1}{2}\left(S_{f,i,t,j,m} + \overline{S_{i,t,j,m}}\right)\left(\ln X_{f,i,t,j,m} - \overline{\ln X_{i,t,j,m}}\right)$$
$$- \sum_{s=t+1}^{t_0}\left(\overline{\ln Q_{s,j,m}} - \overline{\ln Q_{s-1,j,m}}\right) + \sum_{s=t+1}^{t_0}\sum_{i=1}^{n} \frac{1}{2}\left(\overline{S_{i,s,j,m}} + \overline{S_{i,s-1,j,m}}\right)\left(\overline{\ln X_{i,s,j,m}} - \overline{\ln X_{i,s-1,j,m}}\right) \quad (3)$$

for $t<t_0$, where ln $Q_{f,t,j,m}$ stands for the real output (real sales) of firm *f* in year *t*, and ln $X_{f,i,t,j,m}$ represents the natural logarithm of real input of production factor *i* of firm *f* in year *t*. Since there are three types of production factor – capital, labor, and intermediate input – the *n* for the sigma notation is 3 in this case. $S_{f,i,t,j,m}$ is the cost share of production factor *i* at firm *f* in year *t*. $\overline{\ln Q_{t,j,m}}$ denotes the arithmetic average of the log value of the output, in year *t*, of all firms in industry *j* of country *m* to which firm *f* belongs, while $\overline{\ln X_{i,t,j,m}}$ stands for the arithmetic average of the log value of the input of production factor *i*, in year *t*, of all firms in industry *j* of country *m* to which firm *f* belongs. Finally, $\overline{S_{i,t,j,m}}$ is the arithmetic average of the cost share of the input of production factor *i*, in year *t,* of all firms in industry *j* of country *m* to which firm *f* belongs.

The first line of equation (2) calculates the deviation of the TFP level of firm *f* from the average firm-level TFP in a given year, while the second line calculates the sum of the annual changes of the industry average of TFP from the benchmark year. The set of these two calculations makes it possible to conduct both a time-series and a cross-section comparison of firms' TFP levels.

Nominal output[4] and intermediate input were obtained from the financial statements of each firm. The real values of output and input were obtained by deflating nominal output and intermediate input using the price index for each industry[5] in each country. In order to take account of different depreciation rates for different assets, we estimated three types of capital assets –

[4] Output is based on sales after adjusting for increases/decreases in inventories. For wholesalers and retailers, instead of sales, the difference between sales and purchases was used as output.

[5] Following the industry classification of the PPP data of the ICPA project, we reclassified each firm into one of 33 industries, using industry classification information of firms in the stock market where the firm is listed.

structures, machinery, and vehicles – separately, using the perpetual inventory method. Since financial statements only provide the number of employees, the labor input of each firm was obtained by multiplying the number of employees by the average number of hours worked in each industry.

Firm *f*'s cost of capital for each type of asset is obtained by multiplying the capital stock by the capital service price.[6] The capital service prices are calculated by the following equation:

$$c_{f,l,t,j,m} = \frac{1 - z_{f,l,t,i,m}}{1 - u_{t,m}} p_{l,t,m} \{ \lambda_{f,t,j,m} R_{B,t,m} - (1 - u_{t,m})(1 - \lambda_{f,t,j,m}) R_{L,t,m} + \delta_{l,m} - (\ln(p_{l,t+1,m}) - \ln(p_{l,t,m}))\} \quad (4)$$

where $p_{l,t,m}$ stands for the price of investment good l in year t in country m, $u_{t,m}$ is the effective corporate tax rate, $R_{B,t,m}$ is the long-term government bond rate, $R_{L,t\,m}$ is the long-term lending rate, $\lambda_{f,t,j,m}$ is the own-capital ratio of firm f, and $\delta_{l,m}$ is the depreciation rate of asset l in country m. Meanwhile, $z_{f,l,t,j,m}$ is the expected present value of tax saving due to depreciation allowances on one unit of investment, which was obtained using the following equation:

$$z_{f,l,t,j,m} = \frac{u_{t,m} \delta_{l,m}}{\lambda_{f,t,j,m} R_{B,t,m} - (1 - u_{t,m})(1 - \lambda_{f,t,j,m}) R_{L,t,m} + \delta_{l,m}} \quad (5)$$

We obtain the cost for materials and labor from the financial statements of each firm.

The cost shares of the three production factors differ substantially in the three countries. Tables 1 to 3 show changes in the cost share of each production factor for the manufacturing and non-manufacturing sectors in Japan, China and Korea. While in Japan, the cost share of each production factor remained relatively stable, in Korea, the cost share of labor declined from 14.8% in 1990 to 8.7% in 2005 and that of capital fell from 6.9% to 2.2% in the same period. The declines are mirrored by a rise from 78.3% to 89.1% in the cost share of intermediate input, which probably largely reflects the increasing division of labor between firms. Chinese firms are characterized by a low labor cost share compared to their Japanese and Korean counterparts. In the manufacturing sector, the labor cost share in China was 7% in 2004/2005, considerably lower than the 16% for Japan and 9% for Korea.

[6] The method of estimating the capital service price in principle is based on equation (4). However, it should be noted that the estimation methods for Japan, Korea and China slightly differ because of data constraints.

Table 1. Cost Share of Labor (%)

		1985	1990	1995	2000	2004/05
Japan	Manufacturing	15.3	14.5	16.9	16.4	15.8
	Non-manufacturing	18.3	17.3	17.6	16.5	16.2
South Korea	Manufacturing	13.3	14.8	13.2	11.8	8.7
	Non-manufacturing	17.4	17.4	16.0	11.9	7.9
China	Manufacturing				7.6	6.9
	Non-manufacturing				9.5	8.2

Source: Authors' calculations.

Table 2. Cost Share of Capital (%)

		1985	1990	1995	2000	2004/05
Japan	Manufacturing	5.8	6.1	4.6	3.8	3.4
	Non-manufacturing	11.4	11.1	7.9	5.5	4.7
South Korea	Manufacturing	5.8	6.9	5.4	4.2	2.2
	Non-manufacturing	15.4	17.2	12.5	8.5	2.9
China	Manufacturing				8.5	8.7
	Non-manufacturing				12.8	12.3

Source: Authors' calculation.

Table 3. Cost Share of Intermediate Input (%)

		1985	1990	1995	2000	2004/05
Japan	Manufacturing	78.9	79.4	78.5	79.8	80.7
	Non-manufacturing	70.3	71.6	74.5	78	79.1
Korea	Manufacturing	80.8	78.3	81.4	84	89.1
	Non-manufacturing	67.2	65.5	71.5	79.5	89.2
China	Manufacturing				83.8	84.4
	Non-manufacturing				77.8	79.5

Source: Authors' calculations.

2.2. Purchasing Power Parities (PPPs) for Industry Output

In order to compare TFP levels of firms across countries, we need to take account of the difference of price levels of output, intermediate input and investment goods across countries. In other words, we need purchasing power parity (PPP) data in order to convert firms' output and input in the three countries into a common currency unit. In this study, as mentioned earlier, we obtained PPP data for industry output from the results of the ICPA project. When comparing per-capita GDP across countries, usually PPPs based on price information of the final expenditure side are used, such as the PPPs of the International Comparison Program (ICP). But in order to compare TFP levels across countries, we need PPPs for domestic output and intermediate input, which are difficult to estimate from price information of the final expenditure side. Following the methodology of the ICOP project of Groningen University, the ICPA project mainly used information of the unit value of output in addition to final expenditure side price information.

The unit value of product s of industry j in country m, $uv_{s,i,m}$ is computed by dividing the output of product $o_{s,j,m}$ by its quantity $q_{s,j,m}$, as shown below:

$$uv_{s,j,m} = \frac{o_{s,j,m}}{q_{s,j,m}} \tag{6}$$

The unit value ratio of product s of industry j between country A and country B, $UVR_{s,j,B,A}$ is obtained by making an international comparison of unit prices of similar product items:

$$UVR_{s,j,B,A} = \frac{uv_{s,j,A}}{uv_{s,j,B}} \tag{7}$$

The UVR on an industry basis is derived from the UVR on a product basis through the weighted average using the weight of each product in the total output of a particular industry as a whole. Thus, the UVR between country A and country B in industry j is calculated as follows:

$$UVR_{j,B,A} = \sum_{s=1}^{S_j} \omega_{s,j} UVR_{s,j,B,A} \tag{8}$$

where S_j denotes the number of products in industry j, while $\omega_{s,j}$ denotes the production weights of product s in industry j. Each weight is derived as the geometric average of the production share of product s in industry i of country A and that of country B.[7] Figures 1 through 3 show the ICPA results for the PPP converters for the pairs Japan/United States, South Korea/United States, and China/United States for 1999.[8]

(Insert Figures 1, 2 and 3 around here)

2.3. International Comparison of Firms' TFP Level

2.3.1. Constructing a Firm-Level TFP Index for International Comparison

In this subsection, we explain our method for comparing firm-level TFP across countries. Probably, the most straightforward way to compare the productivity of firms in the three countries

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[7] See Timmer and Ypma (2006) for a detailed explanation of the estimation method of PPPs in the ICPA project.

[8] The ICPA project estimated PPPs for just one year, 1997. But using each country's price statistics, we can extrapolate them to other years. Sørensen (2001) claims that the validity of the conversion factor for the productivity comparison between countries can be tested by applying different base year PPPs. However, this kind of comparison is impossible in practice in the case of the PPPs of the ICPA project.

is to convert the value of output, intermediate input and capital assets into the same currency unit, for example, the Japanese Yen value in a certain year, and to pool the data of all listed firms in the same industry across the three countries and directly apply Good, Nadiri and Sickles' method, that is, measure each firm's TFP level by equations (1), (2) and (2). But this time, the variables with upper bars must denote the average value of all listed firms in the same industry across the three countries. For example, equation (2) now becomes

$$\ln TFP_{f,t,j,m} = \left(\ln Q_{f,t,j,m} - \overline{\ln Q_{t,j}}\right) - \sum_{i=1}^{n} \frac{1}{2}\left(S_{f,i,t,j,m} + \overline{S_{i,t,j}}\right)\left(\ln X_{f,i,t,j,m} - \overline{\ln X_{i,t,j}}\right)$$
$$+ \sum_{s=1}^{t}\left(\overline{\ln Q_{s,j}} - \overline{\ln Q_{s-1,j}}\right) - \sum_{s=1}^{t}\sum_{i=1}^{n}\frac{1}{2}\left(\overline{S_{i,s,j}} + \overline{S_{i,s-1,j}}\right)\left(\overline{\ln X_{i,s,j}} - \overline{\ln X_{i,s-1,j}}\right) \quad (2')$$

We first tried this approach but obtained counterintuitive results. In the case of the TFP comparison within each country based on equations (1), (2) and (3), we obtained plausible results. Firms with higher profits and with a reputation of superior competitiveness tend to have higher TFP. But when we pool the data and directly compare the TFP of firms from the three countries using equations such as (2'), we arrived at quite different results in many industries. In this case, firms with higher profits and with a reputation of superior competeviness were frequently found to have lower TFP than firms with a bad performance within the same country.

The main source of these counterintuitive results seems to be the fact that the cost shares are very different across countries. For example, as we have seen in the previous subsection, as a result of low wage rates, the cost share of labor in China is very low. When we use the average cost share of labor of firms across the three countries, the coefficient of the term $\ln X_{f,i,t,j} - \overline{\ln X_{i,t,j}}$ for i = labor in equation (2') becomes much higher than the coefficient of $\ln X_{f,i,t,j,m} - \overline{\ln X_{i,t,j,m}}$ for i = labor and m = China in equation (2). Because of this, the TFP levels derived from equations such as (2') of labor intensive Chinese firms, which are usually quite competitive within the country because of the very low wages, become lower than the TFP levels of capital intensive Chinese firms.

In order to make the results of our international comparison consistent with the actual relative competitiveness of firms within each country, we adopted an eclectic approach. Our method is as follows. When we compare TFP levels within each country we used equations (1), (2) and (3). In this analysis we chose year 1999 as our benchmark year, because Chinese data were only available from 1999. In this way, we measured the TFP level of each firm in comparison with the TFP level of the representative firm, which is calculated from industry average data, in the benchmark year and in the industry of the country to which this firm belongs. Next, for the benchmark year and for each industry, we measured the TFP gap between the South Korean (or Chinese) representative firm and the Japanese representative firm using PPPs. Let $\mu_j^{m,\,\mathrm{Japan}}$ denote this gap between country *m* (South Korea or China) and Japan for industry *j*. Then we measure the TFP level of firm *f* in industry *j* of country *m* in year *t* in comparison with the Japanese representative firm in industry *j* in the benchmark year by $TFP_{f,t,j,m}-\mu_j^{m,\,\mathrm{Japan}}$, where the first term is defined by equations (1), (2) and (3). In the case of Japanese firms, we measure the TFP level of firm *f'* in Japan's industry *j* in year *t* in comparison with the Japanese representative firm in industry *j* in the benchmark year by $TFP_{f,t,j,\,\mathrm{Japan}}$. We measure the TFP gap between firm *f* of country *m* (either South Korea or China) in year *t* and firm *f'* of Japan in year *t'* by $TFP_{f,t,j,m} - TFP_{f,t',j,\,\mathrm{Japan}} - \mu_j^{m,\,\mathrm{Japan}}$. Therefore, the variable, $\mu_j^{m,\,\mathrm{Japan}}$ works as a converter for our international comparison. We explain how we calculate these converters in the following subsection.

2.3.2 International Comparison of the TFP Level in the Benchmark Year

We obtained the converter $\mu_j^{m,\,\mathrm{Japan}}$, which denotes the TFP gap between country *m*'s representative firm and the Japanese representative firm in industry *j* in the benchmark year of 1999, in accordance with the method adopted by Schreyer (2005), which requires a common expression of monetary value to compare output, intermediate input and capital input values. Here, we adopted the Japanese Yen to express monetary values. We converted values in South Korean Won and values in Chinese Yuan into Yen using the PPPs for year 1999 of the ICPA project, which are reported in Motohashi (2006). For output, we used production PPPs by industry to convert firms' output into Yen. For intermediate inputs, we used the simple average of the intermediate input PPPs for energy and for other intermediate inputs. Needless to say, a more precise method would take into consideration the respective weights of energy and other intermediate inputs by industry.

The appropriate measure for input prices in the productivity analysis would be purchaser prices instead producer prices. However, in this study, no adjustment for relative differences of distribution margins across countries is made. In addition, the prices for domestic inputs and imported inputs are not treated separately by using so-called non-competitive import type input-output tables.

For capital input PPPs, assets were divided into structures, machinery and vehicles. For structures, we used the production PPP for construction; for machinery, we used the simple average of the production PPP for the general machinery, electric machinery, and precision machinery industries; and for vehicles, we used the simple average of the output PPP for the motor vehicle and other transportation equipment industry. As for labor input, work hours are directly compared and differences of labor quality resulting from differences in educational backgrounds are not controlled for. At this point, we do not have sufficient information for estimating labor quality at the firm level in each country. Specifically, the following equation was used to estimate TFP at the industry level in 1999:[9]

$$\ln \mu_j^{m,Japan} = \ln \theta_{Q,j}^{m,Japan} - [\overline{\nu_{K,j}^{m,Japan}} \ln \theta_{K,j}^{m,Japan} + \overline{\nu_{L,j}^{m,Japan}} \ln \theta_{L,j}^{m,Japan} + \overline{\nu_{M,j}^{m,Japan}} \ln \theta_{M,j}^{m,Japan}] \tag{9}$$

On the right-hand side of equation (9), from left to right, are the relative output, relative capital input, relative labor input and relative intermediate input in industry *j* of country *m* (either South Korea or China) and Japan, with $\overline{\nu}$ on the right-hand side, also from left to right, showing the average cost shares of capital, labor and intermediate input for industry *j* of country *m* (either South Korea or China) and Japan.

Estimates of the relative output, capital input, labor input and intermediate input, which are necessary to obtain the relative TFP level at the industry level, were derived in the following manner:

(1) Relative output was obtained using the following equation:

$$\ln \theta_{Q,j}^{m,Japan} = \left(\overline{\ln Q_j^{m}} - \overline{\ln Q_j^{Japan}}\right) - \ln q_{Q,j}^{m,Japan} \tag{10}$$

where $\overline{\ln Q_j^{m}}$ and $\overline{\ln Q_j^{Japan}}$ are the arithmetic averages of the log values of the output of all firms in industry *j* in country *m* and Japan in the benchmark year of 1999, while $\ln q_{Q,j}^{m,Japan}$ indicates the output price in country *m* relative to that in Japan in industry *j*.

(2) Relative capital input was obtained using:

$$\ln \theta_{K,j}^{m,Japan} = \sum_{l=1}^{3} \left[\overline{w_{l,j}^{m,Japan}} \left\{ \left(\overline{\ln K_{l,j}^{m}} - \overline{\ln Q_{l,j}^{Japan}} \right) - \ln q_{K,l,j}^{m,Japan} \right\} \right] \tag{11}$$

[9] Since the PPPs estimated by the ICPA project are for 1997, we estimated PPPs for 1999 using information about differences in the growth of the output deflator by industry for the three countries. Specifically, we used the following equation:

$$PPP_{j,1999}^{m,Japan} = PPP_{j,1997}^{m,Japan} \exp(\ln P_{j,1999}^{m} - \ln P_{j,1997}^{m} - \ln P_{j,1999}^{Japan} + \ln P_{j,1997}^{Japan})$$

In the equation above, $PPP_{j,t}^{m,Japan}$ indicates the PPP of industry *j* in year *t* between country *m* and Japan, while $\ln P_{j,t}^{m}$ and $\ln P_{j,t}^{Japan}$ are the natural logarithms of the price indices of industry *j* in year *t* in country *m* and in Japan.

where $\overline{\ln K_{l,j}}^{m}$ and $\overline{\ln K_{l,j}}^{Japan}$ are the arithmetic averages of the log values of the capital stock of the firms for capital good l in industry j in country m and in Japan in the benchmark year, while $\ln q_{K,l,j}^{m,Japan}$ indicates the price in country m relative to that in Japan of capital good l for industry j in the benchmark year. Further, $w_{l,j}^{m,Japan}$ shows the average cost share of capital good l in industry j in the benchmark year in country m and Japan.

(3) Relative input of labor was obtained using the following equation:

$$\ln \theta_{L,j}^{m,Japan} = \overline{\ln LH_{j}^{m}} - \overline{\ln LH_{j}^{Japan}} \tag{12}$$

where $\overline{\ln L_{j}}^{m}$ and $\overline{\ln L_{j}}^{Japan}$ are the arithmetic averages of the log values of the labor input (work hours) of all firms in industry j of country m and of Japan in the benchmark year.

(4) Relative intermediate input was calculated using:

$$\ln \theta_{M,j}^{m,Japan} = \left(\overline{\ln M_{j}^{m}} - \overline{\ln M_{j}^{Japan}}\right) - \ln q_{M,j}^{m,Japan} \tag{13}$$

where $\overline{\ln M_{j}}^{m}$ and $\overline{\ln M_{j}}^{Japan}$ are the arithmetic averages of the log values of intermediate input of all firms in industry j of country m and of Japan in the benchmark year, while $\ln q_{M,j}^{m,Japan}$ corresponds to the intermediate input price in country m relative to that in Japan in industry j in the benchmark year.

3. Data Used

3.1. Representativeness of the Data

As explained in Section 1, we calculated the TFP of almost all listed firms in Japan, Korea and China. One caveat with regard to our database is that it covers only listed firms. Especially in developing economies, such as China, listed firms may have substantially different characteristics from ordinary unlisted firms and their activities cover a relatively small part of the whole economy. To assess the seriousness of this problem, we examine the characteristics of the stock market in each country. With regard to data, in addition to the results of the ICPA project on PPPs and the databases on listed firms in each country, we also used various industry-level and macro-level statistics of each country, such as deflators and interest rates. The sources for such additional data are summarized in the appendix.

In this subsection we examine the "representativeness" of the firms included in our database, that is, the role that the firms covered in the database play in their respective economies. We do so by examining the extent to which these firms account for the national total of various indicators.

Looking at the ratio of gross sales of all listed firms to nominal gross domestic product (GDP) in Japan, China and Korea shows that this ratio is high for Japan and Korea at 80.5% and 94.0%, respectively, but very low for China at 8.1% (see Table 4). This means that developments regarding listed firms in China are unlikely to reflect trends for Chinese firms as a whole.

Table 5 shows the respective shares of the firms covered here in terms of the number of employees, the total number of firms, tangible fixed assets, sales, gross assets, operating profits and recurring profits. The information for these indicators was obtained from to the *Basic Survey on Business Activities by Enterprises* for Japan, the *Mining and Manufacturing Survey* for Korea, and the *China Industry Economy Statistical Yearbook* and the *China Statistical Yearbook* for China. While the data for Japan encompass almost all sectors, including not only manufacturing but also non-manufacturing, the Korean data are limited to mining and manufacturing, while the Chinese data include mining, gas and electricity, and manufacturing. The data for Japan and China are for 2004, while those for Korea are for 2003.

Table 4. Ratio of Listed Firms' Gross Sales to Nominal GDP (2000, %)

	Ratio of Listed Firms' Gross Sales to Nominal GDP (%)
Japan	80.5
Korea	94.0
China	8.1

Source: Authors' calculations.

Table 5. Shares of Firms Included in the Databases for Japan, China and Korea

Japan (persons, mil. Yen)

	Number of Employees	Sales	Operating Profits	Recurring Profits	Number of Companies
Basic Survey on Business Activities by Enterprises	11,972,207	647,113,748	25,987,004	26,768,936	28,314
DB (EALC 2007)	4,484,085	428,009,019	20,422,920	20,576,026	3,521
Share (%)	37.5	66.1	78.6	76.9	12.4

Korea (persons, mil. KRW)

	Number of Employees	Tangible Fixed Assets	Sales
Mining and Manufacturing Survey	2,752,175	679,456,909	263,697,095
DB (EALC 2007)	769,810	392,527,912	157,045,307
Share (%)	28.0	59.6	57.8

China （person, bil.RMB）

	Number of Employees	Tangible Fixed Assets	Output	Gross Assets	Profits
China Statistical Yearbook, etc.	60,990,000	12,576	18,722	19,526	1,134
DB (EALC 2007)	3,200,000	1,845	2,362	2,723	86
Share (%)	5.2	14.7	12.6	13.9	7.6

Source: Authors' calculations.

For Japan, the firms in our database account for only a relatively small share of 12.4% of the total number of firms and 37.5% of employees, but for 66.1% of sales and 78.6% of profits. The picture is similar in Korea, where the firms included in the database account for only 28.0% of the total number of employees but for close to 60% of sales and tangible fixed assets.

For China, on the other hand, the share accounted for by the listed firms covered in our database compared to Japan and Korea are low for all indicators, raising doubts about the representativeness of these firms. As discussed in the next section, this situation may be due to the difference in the environment surrounding the listing of firms, including the fact that China's stock markets (in Shanghai and Shenzhen) were established only relatively recently, in 1990, and that a multitude of regulations about stock market listings exists. It seems that these regulations make it difficult to list, so therefore fewer firms in China are listed.

3.2. Overview of Stock Markets in Japan, China and Korea

Having examined the "representativeness" of firms included in our database, we now provide an overview of stock markets in Japan, China and Korea where these firms are listed. In developing economies, listing criteria often differ from those in developed economies because of regulations, and this may affect the "quality" – i.e., the performance or productivity – of the firms that are listed. For this reason, it is useful to have a look at the characteristics of stock markets in the three countries, including market sizes and listing criteria.

In terms of market value, the Tokyo Stock Exchange (TSE) is the largest among the Asian stock markets and one of the largest in the world. The TSE, in its current form, was established in 1949, but the exchange has a history of over 100 years of trading in stocks, as its predecessor, the "Tokyo Stock Exchange Co., Ltd." was established in 1878 and started stock trading under the "Stock Exchange Ordinance" enacted in the same year.

Table 6. Overview of Stock Exchanges in Japan, China and Korea
(As of the end of Aug, 2007)

	Japan (Tokyo Stock Exchange)	Korea (Korea Stock Exchange)	China (Shanghai Stock Exchange)
Number of Listed Enterprises	2419	736	852
Market Value (trillion US$)	4.5	1.0	2.3
Year of Establishment	1949	1956	1990

Source: Websites of the Tokyo Stock Exchange, the Korea Stock Exchange, and the Shanghai Stock Exchange.

In Korea, the main platform for securities trading until recently was the Korea Stock Exchange (KSE), established in 1956. The full-fledged development of the KSE began in the latter half of the 1960s when the number of listed firms increased substantially as the market-related legal framework was put in place, including the enactment of the Securities and Exchange Law. In the wake of the recent rapid changes in the environment surrounding capital markets, Korea, in 2005, set out to strengthen market administration by integrating operators of the country's securities markets. The KSE, KOSDAQ (an over-the-counter market) and futures markets got together to launch the Korea Exchange (KRX).

China's stock markets shifted into full swing in 1990 with the establishment of stock exchanges in Shanghai and Shenzhen, and the Shanghai Stock Exchange has already overtaken the KSE in terms of market value. However, China's stock market system is still somewhat different from other markets in a number of respects. At the inception of the two stock exchanges, the listing of shares was deemed an easy way for state-owned enterprises to raise funds. From the early 1990s up until around 2001, firms to be exchange-listed were selected under a sort of regional quota system, with the selection virtually left to the discretion of local governments, instead of qualified firms being listed in accordance with market principles.

Under these circumstances, even enterprises with a poor earnings performance were able to get shares listed if they were of importance to the local government concerned in terms of local employment and tax revenues. Thus, firms that were not at all fit for the public to invest in made their debut on the stock market. As a large number of such firms remains, the overall quality of listed firms is low on average.

3.3 Number of Listed Firms in Japan, China and Korea

The number of listed firms in Japan[10] has more than doubled over the last 20 years from 1,402 in 1985 to 3,521 in 2004 (see Table 7). In particular, the number of start-up firms listed has shown a remarkable increase, with the number of start-ups listed on JASDAQ and other markets growing by 1,138, accounting for the bulk of the increase in the number of listed firms over the same period. In 2004, the number of listed non-manufacturing firms, at 1,863, exceeded that of listed manufacturing firms, which was 1,658, while back in 1985, listed manufacturers outnumbered listed non-manufacturers by a large margin. This reversal over the past two decades stems chiefly from the increase in the number of firms that belong to industries such as commercial and other private-sector services.

The number of listed firms in Korea[11] increased considerably from 619 in 1985 to 1,563 in 2005 (see Table 8). However, while the number of listed firms rose steadily until 2000, it declined slightly from 2000 through 2005. Distinguishing between manufacturers and non-manufacturers, manufacturers outnumbered non-manufacturers considerably, by 1,139 to 424, in 2005. Manufacturers also led non-manufacturers by a considerable margin of 661 to 283 in terms of the increase in the number of listed firms between 1985 and 2005. In the manufacturing sector, such industries as general machinery and electric machinery saw a remarkable expansion in the number of listed firms over the same period.

[10] Corporate data on listed firms in Japan are based on information on the listing status as of 2004. Suppose that Firm A got listed on the first section of an exchange in 2004, we then regard Firm A as if it had been on the first section all along even if Firm A, in fact, had been on the second section before 2004.

[11] When a firm was listed on an exchange in a given year, then, in terms of the data used, we regarded that firm as listed on that particular exchange all along before the actual listing. However, when a firm was de-listed from an exchange, we did not use data for that firm following the year of delisting.

The number of listed firms in China[12] in 2004 stood at 1,042, with the number of firms listed in Shanghai, at 641, far exceeding the 401 firms listed in Shenzhen (see Table 9). In 2004, the number of listed firms in the manufacturing sector, at 707, far outstripped that of listed firms in the non-manufacturing, which stood at 335, with many of the listed firms coming from such industries as printing and electric machinery.

Table 7. Number of Listed Firms by Stock Exchange (Japan)

	1985	1990	1995	2000	2004
1st Section	1,029	1,187	1,322	1,482	1,558
2nd Section	373	486	634	755	805
JASDAQ	0	232	465	733	908
Other	0	0	0	82	230
Total	1,402	1,905	2,421	3,052	3,501

Source: Authors' calculations.

Table 8. Number of Listed Firms by Stock Exchange (Korea)

	1985	1990	1995	2000	2005
KSE	485	535	545	621	613
KOSDA	134	292	551	958	950
Total	619	827	1,096	1,579	1,563

Source: Authors' calculations.

Table 9. Number of Listed Firms by Stock Exchange (China)

	1999	2000	2001	2002	2003	2004
Shanghai	338	376	470	534	597	641
Shenzhen	322	370	399	406	403	401
Total	660	746	869	940	1,000	1,042

Source: Authors' calculations.

Table 10. Number of Listed Firms by Sectors

		1985	1990	1995	2000	2004
Japan	Manufacturing	1,142	1,423	1,623	1,734	1,658
	Non-manuf.	586	910	1,250	1,676	1,863
Korea	Manufacturing	478	649	847	1,157	1,139*
	Non-manuf.	141	178	249	422	424*

[12] Unlike in the case of Japan or Korea, data on listed Chinese firms are simply data for firms listed in years under review, without any of the considerations discussed in footnotes 11 and 12.

China	Manufacturing				481	707
	Non-manuf.				265	335

* Data for 2005 rather than 2004.
Source: Authors' calculations.

4. Comparison of Firm-Level TFP in Japan, China and Korea

4.1 *Comparison of TFP Growth in Japan, China and Korea: Manufacturing and Non-manufacturing*[13]

The growth rate of TFP in Japan's manufacturing sector slowed down markedly in the first half of the 1990s before accelerating again in the second half of that decade and again in the early 2000s. In Korea, the TFP growth rate turned negative during the financial crisis in the latter half of the 1990s but was back in positive territory during 2000-2004. Yet, compared with the late 1980s and early 1990s, Korea's rate of TFP growth has remained low. The growth rate of TFP in China in 2000-2004 was just below 7%, far higher than for manufacturers in Japan and Korea.

In the non-manufacturing sector, TFP growth tended to be low relative to the manufacturing sector until 2000 in both Japan and Korea. In 2000-2004, however, the rate of non-manufacturing TFP growth topped 2% in Japan and 3% in Korea to exceed that for the manufacturing sector. The TFP growth in China's non-manufacturing sector also exceeded that of the manufacturing sector, registering growth of over 8%.

Table 11. TFP Growth Rate (percent per annum)

		1985-1990	1990-1995	1995-2000	2000-2004
Japan	manufacturing	1.07	0.59	1.58	1.77
	Non-manufacturing	1.97	-1.25	0.92	2.14
Korea	manufacturing	4.04	5.62	-0.75	2.73
	Non-manufacturing	-0.04	1.23	0.93	3.31
China	manufacturing				6.98
	Non-manufacturing				8.16

Source: Authors' calculations.

4.2 *Comparison of the TFP Level of Representative Firms in Japan, China and Korea*

Figures 4 through 7 show a comparison of the TFP levels of one to three representative firms[14] from Japan, Korea and China in four different industries: the chemical, the primary metal

[13] TFP growth in the manufacturing and the non-manufacturing sector is calculated as the average of firms' TFP growth weighted by their output share in their respective sector.
[14] Our selection of representative firms is based on the scale of firms' sales and name recognition.

manufacturing, the electric machinery and equipment manufacturing, and the automobile and auto parts manufacturing industry.

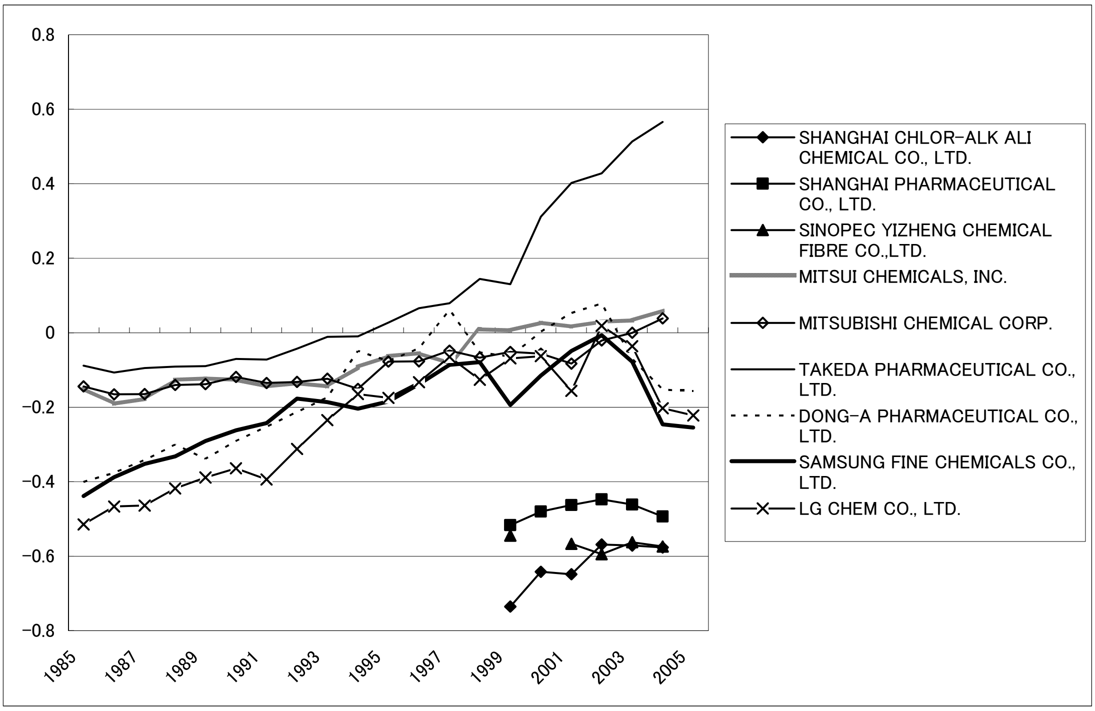
For the chemical industry (including pharmaceuticals), we selected two petrochemical firms and one pharmaceutical firm from each country (see Figure 4). The productivity of Japan's leading pharmaceutical firm, Takeda Pharmaceutical Co., Ltd. has increased rapidly since 2000, not only far exceeding the TFP levels of Korean and Chinese pharmaceutical firms but also outstripping the TFP levels of major Japanese petrochemical firms.

In the primary metal sector (see Figure 5), POSCO of Korea boosted its productivity to match that of Nippon Steel Corporation in the first half of the 1990s. But its productivity later plummeted in the mid-2000s to lag far behind the two major Japanese steelmakers. The TFP levels of Dongkuk Steel Mill Co., Ltd., of Korea and of Angang New Steel Co., Ltd., of China have not improved much, staying low relative to those of their Japanese counterparts.

In the electric machinery industry, Korean firms raised their TFP levels markedly (see Figure 6). Since 2000, the TFP levels of LG Electronics Inc. and Samsung Electronics Co., Ltd., have been higher than those of Matsushita Electric Industrial Co., Ltd. and Toshiba Corporation. The TFP levels of Chinese electric machinery makers remain low relative to those of their Japanese and Korean rivals.

In the automobile and auto parts manufacturing industry (Figure 7), the TFP levels of Toyota Motor Corporation and Honda Motor Co., Ltd., of Japan are considerably higher than those of their two Korean and two Chinese counterparts. The TFP levels of Hyundai Motor Company and Kia Motors Corporation of Korea are only about half those of the Japanese automakers.

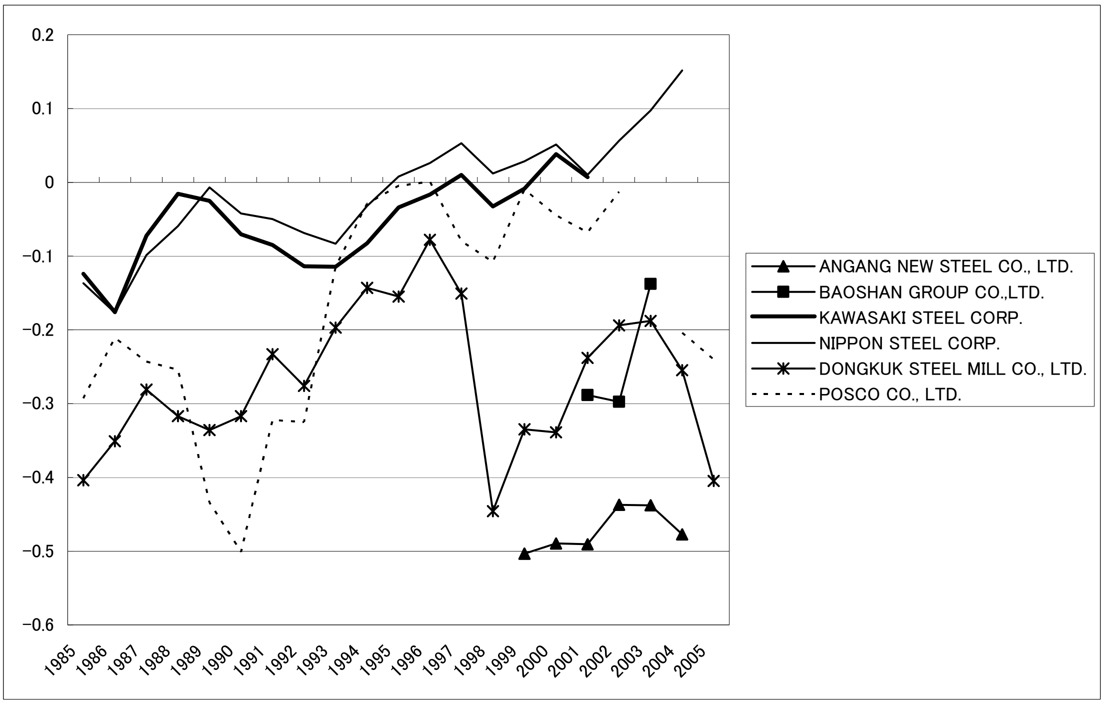
Figure 4. Firms' TFP in the Chemical Industry (Representative Firms of the 3 Countries)



Source: Authors' calculations.

Figure 5. Firms' TFP in the Primary Metal Manufacturing Industry

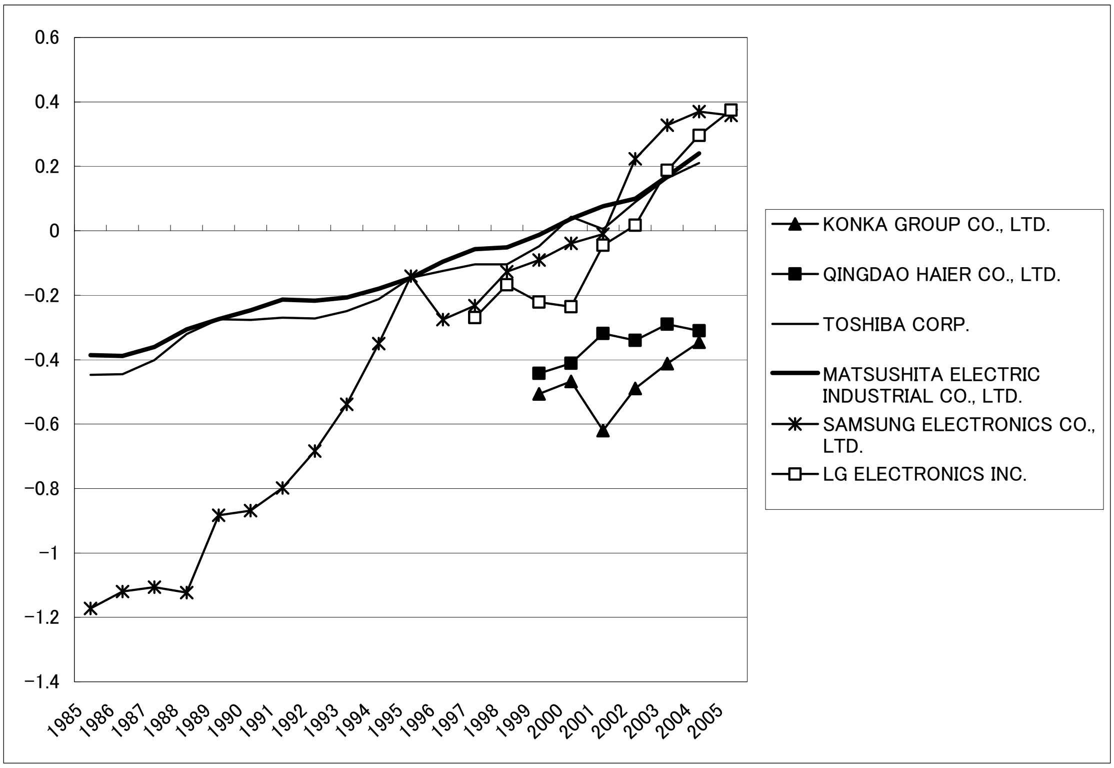
(Representative Firms of the 3 Countries)



Source: Authors' calculations.

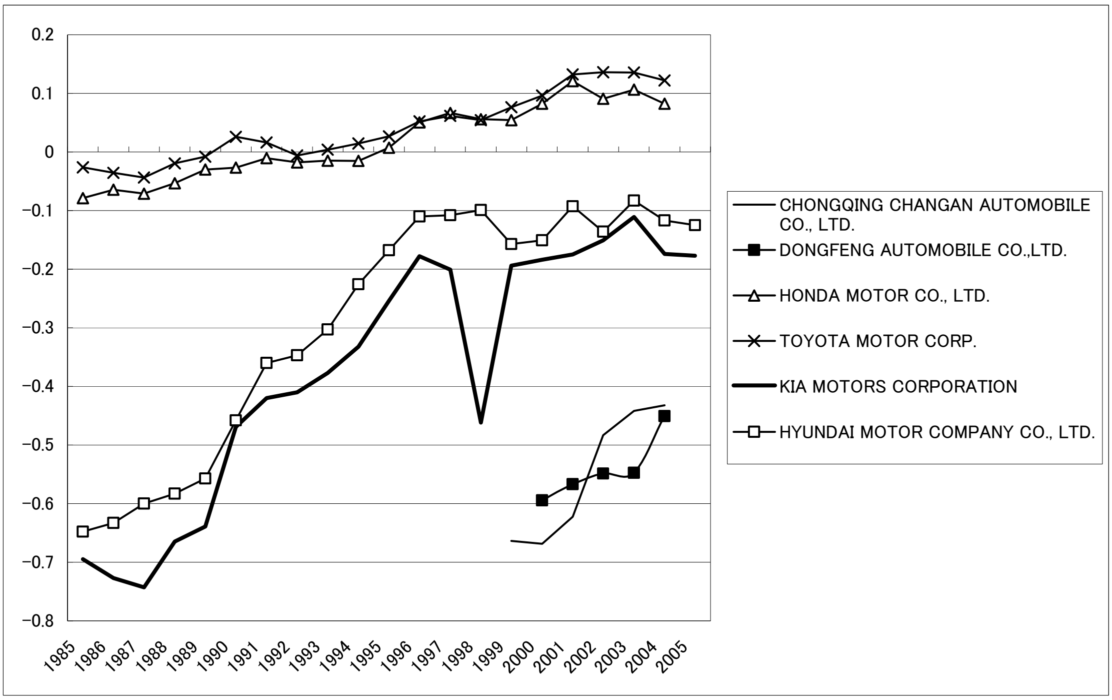
Figure 6. Firms' TFP in the Electric Machinery Industry

(Representative Firms of the 3 Countries)



Source: Authors' calculations.

Figure 7. Firms' TFP in the Automobile and Auto Accessories Manufacturing Industry (Representative Firms of the 3 Countries)



Source: Authors' calculations.

5. Conclusion

The study group on the Creation of a Productivity Database on Japanese, Chinese, and South Korean firms at JCER compiled the EALC 2007 Database and this paper explained the methodology employed. To compare the TFP level of firms in these countries, we first estimated the TFP of firms in each country using the method of Good, Nadiri and Sickles (1997). Then we estimated the relative TFP by industry in the benchmark year using Japanese industries as benchmarks and combined the estimated TFP of firms. When estimating relative TFP by industry for Korea and China, we applied the industry-level price estimates of the three countries from the ICPA project and converted industry output and input into the same currency unit (Japanese Yen). However, regarding the intermediate input price estimation, several problems still have to be addressed. First, we should take into account the weights of energy inputs and other inputs using input-output tables and other sources. Second, we should use purchaser prices rather than producer prices. And third, we should take into account differences in domestic prices and import prices.

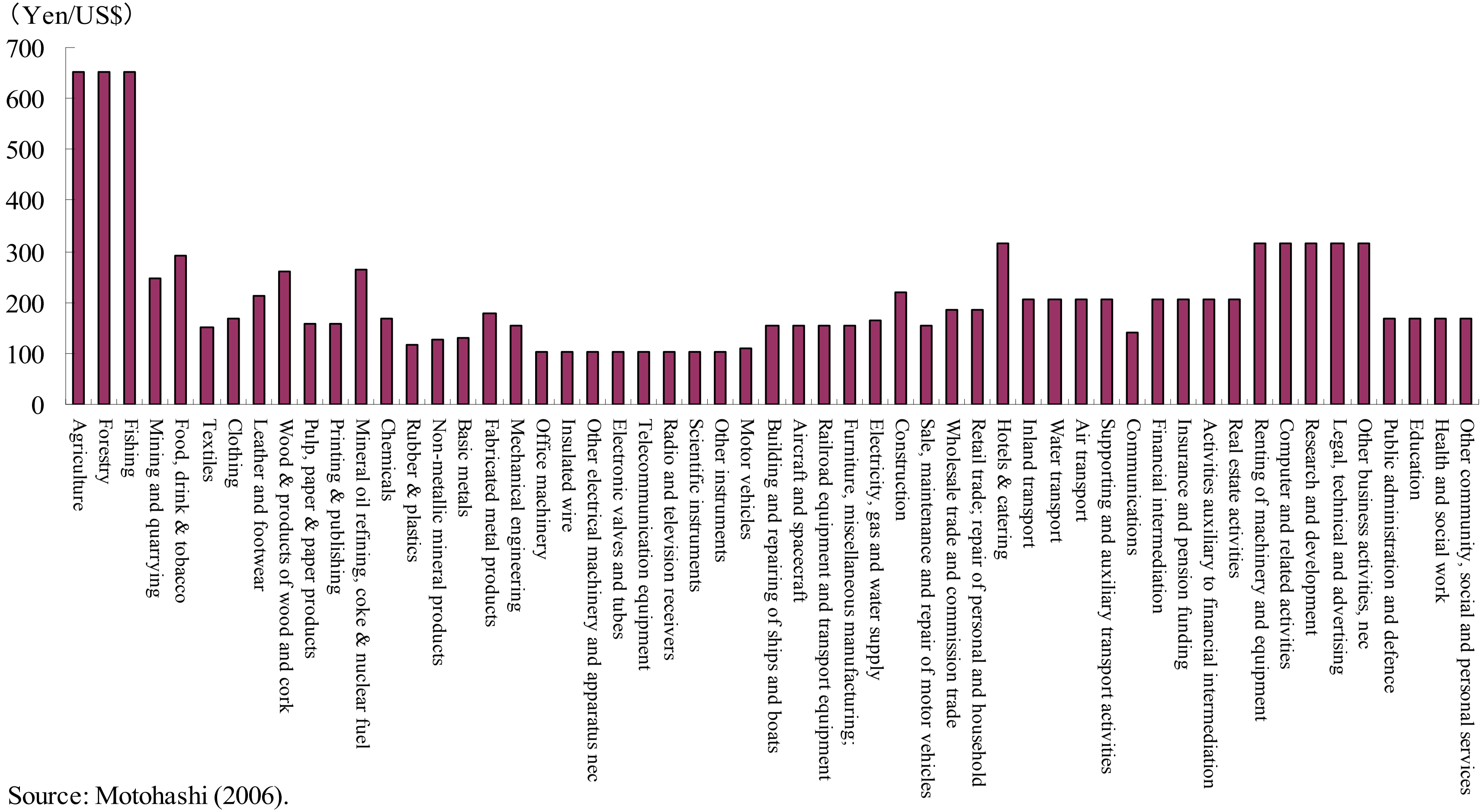
In order to deflate each firm's output, we used the output deflator of the industry in which this firm is classified. However, many large firms diversify their activities, which are not necessarily limited to one industry. How to deal with changes in the composition of individual firms' activities across industries is an important issue to be addressed in the future.

Another topic that it might be interesting to explore is the effect of changing production networks and inter-firm trade on firms' productivity. In production networks, transaction prices are often affected by the relative bargaining power of suppliers and customers. However, it is very difficult to obtain data on inter-firm transactions that would be necessary for this kind of analysis.

A further possible extension would be to compare the TFP of firms in the three countries with that of U.S. firms, since many of the firms at the world technology frontier hail from the United States. The improvements and potential extensions mentioned here are left for future studies.

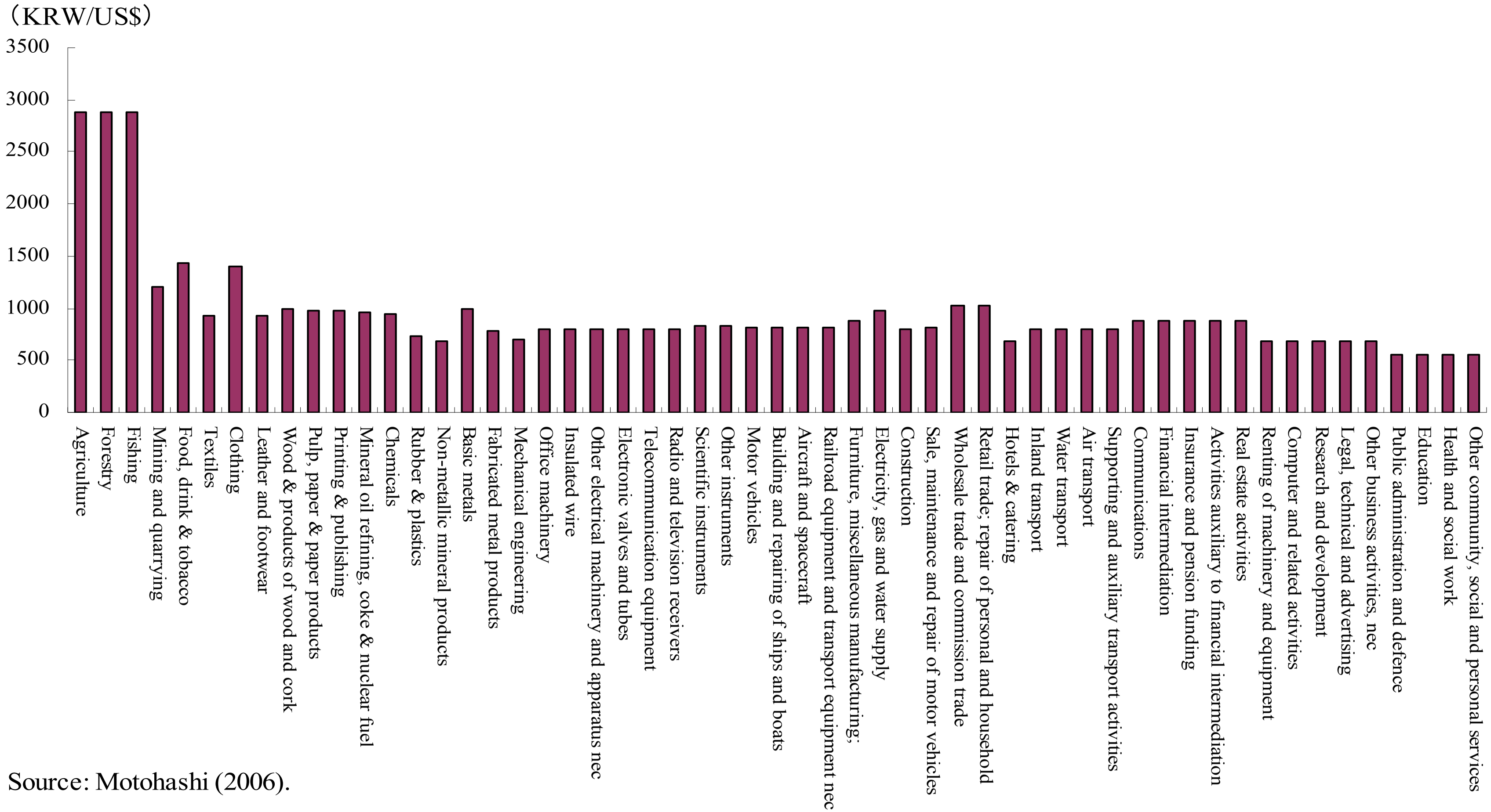
Although the results we obtained should be interpreted with caution because of the problems mentioned above, what they suggest is that, generally, the productivity of Japanese firms is still higher than that of their Chinese and Korean counterparts. Yet, the productivity of Korean firms is increasing rapidly and some firms, particularly in the electric machinery sector, have in fact overtaken their Japanese rivals.

Fig.1 Estimation of Japan's Purchasing Power Parity on a Production Basis



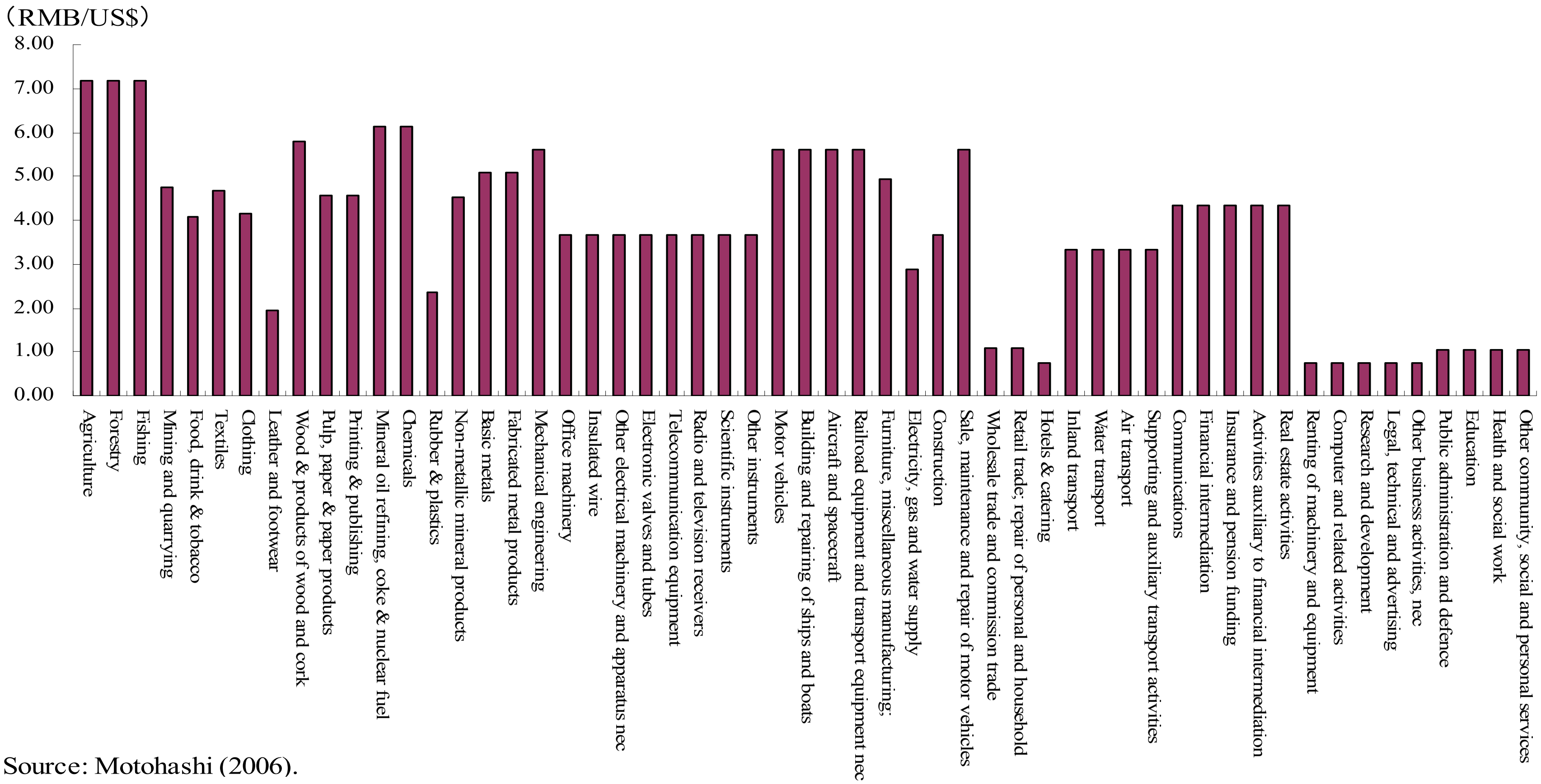
Source: Motohashi (2006).

Fig.2 Estimation of Korea's Purchasing Power Parity on a Production Basis



Source: Motohashi (2006).

Fig.3 Estimation of China's Purchasing Power Parity on a Production Basis



Source: Motohashi (2006).

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Appendix

In addition to the results of the ICPA project on PPPs, we used databases on listed firms for each country and some industry-level and macro-level data for each country, such as deflators and interest rates. In this appendix, we summarize the sources of such data.

Japan

We obtained firm-level data of Japanese listed firms from the Development Bank of Japan (DBJ) Database.

Deflator for output and material inputs

Deflator for output: Japan Industrial Productivity Database 2006 (JIP 2006).

Deflator for material inputs: JIP 2006.

The JIP 2006 database provides deflators up to 2002. We extended these up to 2004 using SNA deflators.

Labor input

Number of employees: DBJ Database.

Industry average working hours: JIP 2006.

Capital cost

Interest rate: Long-term lending rates are taken from http://www.boj.or.jp/theme/research/stat/dl/kinri/prime/index.htm,

and long-term government bond rates are from http://www.boj.or.jp/theme/research/stat/market/bond_mk/bondyield/index.htm

of the Bank of Japan website.

Corporate tax rate: We obtained the data from http://www.mof.go.jp/jouhou/syuzei/siryou/houzin.htm

of the Ministry of Finance website.

Own capital ratio: DBJ Database

Deflator: Domestic Corporate Goods Price Index, Bank of Japan.

Depreciation rate of each type of asset: JIP 2006.

South Korea

We obtained firm-level data of South Korean listed firms from the Korea Information Service (KIS) Database.

Deflator for output and material inputs

Deflator for output: PPI (Producers Price Index) of the Bank of Korea (BOK).

Deflator for material inputs: 1984-2002: Pyo, Rhee and Ha (2006); 2003-2005: Intermediate Goods and Material Deflator of the BOK.

Labor input

Number of employees: KIS Database.

Industry average working hours: *Monthly Labor Survey*, Ministry of Labor.

Capital cost

Interest rate: BOK data.

Corporate tax rate: Kim, Park, and Ahn (2003).

Own capital ratio: KIS Database.

Deflators: Deflator for buildings and structures: Intermediate Goods and Material Deflator for Construction of the BOK; deflator for machinery, tools, and vehicles: Total Fixed Asset Formation Deflator of BOK.

Depreciation rate: Pyo (2002).

China

We obtained firm-level data of Chinese listed firms from the China Stock Market (CSMAR) Database provided by Guo Tai An Group.

Deflator for output and material inputs

Deflator for output: National Bureau of Statistics (NBS), except for the output deflators for agriculture and service sectors, which are from *China Statistical Yearbook.*

Deflator for material inputs: We estimated this using data from the NBS and the *Input-Output Table 2002.*

Labor input

Numbers of employees: CSMAR Database.

Industry average labor hours: Estimated based on data from the *Population Survey 1995* and Yang (2003).

Capital cost

Interest rate: The People's Bank of China (PBC).

Corporate tax rate: CSMAR Database.

Deflator: We estimated this using data from the NBS and the *Input-Output Table 2002*. We used the average price of four types of capital goods: machinery, tools, vehicles, and buildings and structures.

Depreciation rate: Fraumeni (1997).