RIETI Discussion Paper Series 13-E-043

R&D Investment and Productivity: A comparative study of Japanese and Korean firms

YoungGak KIM
Senshu University

ITO Keiko
RIETI

Research Institute of Economy, Trade & Industry, IAA
The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

RIETI Discussion Paper Series 13-E-043
May 2013

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YoungGak KIM †
Senshu University ‡

ITO Keiko
Senshu University and Research Institute of Economy, Trade and Industry

Abstract

In this paper, using a large-scale dataset covering both Japanese and Korean firms, we examine the differences in performance and research and development (R&D) activities between them. We find that Japanese firms tend to be more productive in terms of total factor productivity (TFP), and that the productivity gap has not been narrowing in most industries. However, Korean firms are superior in terms of labor productivity and profitability. On the other hand, in recent years, Korean firms on average have tended to have a higher R&D intensity. In particular, smaller Korean firms have been actively increasing their R&D expenditures.

We also find that the rate of return on R&D for large/productive firms is much higher in Korea, while that for small/less productive firms does not significantly differ. The relatively low rate of return for small/less productive firms may explain why Korea's average TFP level is not catching up with that of Japan. On the other hand, the rate of return on R&D for large firms is low in Japan, warranting further investigation on the factors underlying this.

Keywords: Productivity; R&D; Japan; Korea; International comparison; Industry-level purchasing power parity
JEL classification: O30, C23, L60, O53

*This study was conducted as part of the East Asian Firm Productivity project undertaken by the Research Institute of Economy, Trade and Industry (RIETI). We thank Hyeog Ug Kwon and other participants in the RIETI project and the workshops at RIETI and KDI (Korea Development Institute) for their helpful comments and suggestions. We gratefully acknowledge the financial support from the Japan Society for the Promotion of Science in the form of a Grant-in-Aid for Scientific Research (Nos. 23243050 and 23683003).
† Faculty of Economics, Senshu University. E-mail: ykim@isc.senshu-u.ac.jp
‡ Faculty of Economics, Senshu University. E-mail: keiko-i@isc.senshu-u.ac.jp

1. Introduction

While Korean companies such as Samsung and Hyundai in recent years have been very successful in gaining substantial global market shares, the international market shares of Japanese firms have tended to decline, particularly in the case of final goods and consumer products. In parallel to this, Korea's research and development (R&D) intensity (measured in terms of the ratio of R&D expenditures to GDP) has steadily increased and surpassed Japan's R&D intensity for the first time in 2009. Given these developments, we conjecture that R&D activities have played an important role in the technological advances and the competitiveness of Korean firms. The growing competitiveness of Korean firms has been attracting increasing public attention and the *White Paper on International Economy and Trade 2012* released by the Japanese Ministry of Economy, Trade and Industry in fact presents a comparative analysis of Japan, Korea, and Germany, focusing on the international business activities of firms from these countries. Nevertheless, our knowledge on the mechanisms of how R&D generates growth is still limited, and it is not clear how productive Korean firms are relative to other firms and whether R&D investment is one of the drivers that has contributed to their surge in international markets, especially when compared with their Japanese counterparts.

In this paper, using a large-scale dataset which covers both Japanese and Korean firms, we explore differences in the performance and R&D activities of Japanese and Korean firms and examine whether R&D contributed to firms' productivity growth. We are particularly interested in the role of R&D in the catch-up process of Korean firms. This paper contributes to the existing literature in at least three ways. First, we examine the differences in productivity *levels* between Japanese and Korean firms. While cross-country comparisons of productivity *growth* rates are quite common, cross-country comparisons of productivity *levels* are very rare, mainly due to difficulties in the measurement of real inputs and outputs in internationally comparative units. Utilizing the industry-specific purchasing power parity (PPP)-adjusted exchange rates estimated in the International Comparison of Productivity among Pan-Pacific Countries (ICPA) project conducted at the Research Institute of Economy, Trade and Industry (RIETI), we measure the firm-level productivity *levels* of both Japanese and Korean firms in a way that allows international comparison and examine differences in the average levels and evolution of productivity of firms in both countries. Second, we conduct this comparison using a large-scale dataset that includes relatively small, unlisted firms. As described in the next section, as far as we are aware, to date no international comparative analyses including smaller firms have yet been conducted for these countries. This study thus provides new evidence on productivity differences between firms in the two countries including, for the first time, smaller firms.

Third, we add to the literature on the relationship between R&D efforts and productivity growth by comparing the rate of return on R&D for firms in both countries. In particular, using our large-scale firm-level dataset covering relatively small, unlisted firms, we provide empirical evidence on differences in the rate of return on R&D by firm size for both countries, which may help to understand the process of Korea's productivity catch-up.

The paper starts out by providing an overview of various characteristics of Japanese and Korean firms, such as their size, R&D intensity, and productivity. We then conduct a simple regression analysis to determine in which industries Korean firms' productivity is higher than that of Japanese firms on average and whether Korean productivity is catching up with Japanese productivity. We find that Korean firms are still lagging behind Japanese firms on average in terms of total factor productivity (TFP), although Korean firms enjoy higher average labor productivity and profitability. The latter half of the paper then focuses on R&D investment of firms in both countries, and we estimate the rate of return on R&D investment for both countries in order to provide a possible explanation for the persistent productivity gap between the two.

The remainder of this paper is organized as follows. Section 2 briefly reviews the related literature, while Section 3 describes the dataset used as well as the methodology employed to construct a TFP measure which is comparable across countries. In Sections 4 and 5, we then conduct a comparison of the characteristics of Japanese and Korean firms, focusing on TFP as well as single factor productivity measures and the distribution of R&D activities across firms. Next, in Section 6, we conduct an econometric analysis in order to examine the impact of investment in R&D on productivity growth. Finally, Section 7 presents a summary of our findings and discusses their implications.

2. Literature Review

This paper is closely related to two research strands. The first is the measurement of internationally comparable productivity levels, while the second is the role of R&D in productivity growth.

As for international productivity comparisons, as highlighted above, a key challenge often is to measure productivity in an internationally comparable unit. In an ideal situation, one would use quality-adjusted quantity data on inputs and outputs for the measurement of productivity. However, in most firm-level databases, input and output amounts are available only on a value basis, not on a quantity basis. Moreover, input and output values are usually expressed in local currency units and it is necessary to convert these values to one currency unit when conducting an international comparison. One possible way to convert values in one currency into another would be to use the nominal exchange rate; however, the nominal exchange rate is not the most appropriate rate for conversion. In order to obtain a productivity measure that is comparable across countries and over time, we need real output and inputs adjusted for cross-country and time-series differences in price levels. Therefore, it is more appropriate to use the PPP-adjusted exchange rate, which takes cross-country differences in price levels into account, than the nominal exchange rate. Moreover, the evolution of price levels usually differs across industries, so that it is preferable to use industry-specific PPP rates than the macro-level PPP rate.

Given these challenges, international comparative studies of productivity *levels* remain very scarce and limited in scope, although a small number of attempts for a very limited number of countries have been made, such as Jorgenson et al. (1987). However, in recent years, industry-level PPP rates for the United States, Canada, and European countries have been estimated as part of the International Comparisons of Output and Productivity (ICOP) project conducted by EU KLEMS, while industry-level PPP rates for Asian countries (Japan, Korea, China, and Taiwan) have been estimated as part of the ICPA product conducted by RIETI, which make it possible to estimate internationally comparable productivity levels for industries and firms for these countries.

There are several firm-level studies which take internationally comparable productivity levels into account using the industry-specific PPP rates estimated by these research projects.[1] For example, Bartelsman et al. (2008) examine the productivity growth of British firms from the perspective of productivity catch-up towards the global frontier firms. Ito et al. (2008) and Fukao et al. (2011), using the industry-specific PPP rates estimated by the ICPA project, compare the productivity levels and their distribution of listed firms in Japan, Korea, and China (the latter study also includes listed firms in Taiwan). According to these studies, the TFP levels of Korean and Chinese firms (as well as Taiwanese firms in the latter study) are on average still lower than those of their Japanese counterparts. However, these studies also find that the TFP levels of firms from these countries have been catching up towards the TFP levels of Japanese firms.[2] Further, Jung and Lee (2010), analyzing the productivity gap between Korean and Japanese firms, find that Korean firms' TFP catch-up with Japanese firms is more likely to occur in sectors where technologies are more explicit and easily embodied in imported equipment and in sectors with more monopolistic market structures.

Although these studies provide a lot of interesting findings regarding the productivity gap among firms in Japan, Korea, China, and Taiwan, the analyses in these studies are limited to listed firms. The productivity levels of smaller, unlisted firms in these Asian countries, as well as the distribution of productivity levels, are not examined in these studies. This paper tries to fill this gap by including smaller, unlisted firms in the analysis.

Turning to the second strand of the literature that this study falls into, namely the

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[1] Industry-level productivity comparisons have also been conducted in the EU KLEMS project for the United States, Japan, and several European countries. See Inklaar and Timmer (2008).

[2] Bellone et al. (2013) compare the productivity levels and their distribution of firms in Japan and France.

relationship between R&D investment and productivity growth, the available literature is quite substantial. A wide range of industry- and/or firm-level empirical studies on this issue have been conducted for a variety of developed countries, including Japan (e.g., Griliches and Mairesse 1990, Wakelin 2001, Inui and Kwon 2005). However, such studies for Korea, particularly studies based on firm-level data, are very scarce. An exception is the study by Heshmati and Kim (2011), who, using firm-level data from the KIS Database for 1986 to 2002, found that growth in R&D investment per employee significantly and positively influences labor productivity growth. They further found that the impact of increases in R&D per employee on labor productivity growth was much larger than the impact of increases in capital per employee, highlighting the importance of the contribution of R&D investment to labor productivity growth. Moreover, they found a significant feedback effect from labor productivity growth to R&D investment growth, suggesting that growth in labor productivity can also cause growth in R&D investment. Heshmati and Kim (2011) consequently argue that productivity growth and R&D investment are mutually reinforcing.

These previous studies provide estimates of the magnitude of the impact of R&D investment on productivity growth for each country, and based on these estimates, it is possible to gain a general sense of the order of magnitude of the contribution of R&D investment. However, these estimates are based on different datasets for different countries and periods, and are often based on somewhat different analytical frameworks. Therefore, it is difficult to directly compare the estimated magnitudes of the impact across countries.

This paper uses a pooled firm-level dataset for Japan and Korea and estimates the rate of return on R&D in a manner that makes it possible to compare the results for the two countries. Comparing the estimated rates of return, we will investigate the role of R&D activities in productivity growth for Japanese and Korean firms.

3. Data

3.1 Data Sources

The firm-level panel data for Japan are taken from the *Basic Survey of Japanese Business Structure and Activities (BSBSA)* conducted annually by the Ministry of Economy, Trade and Industry (METI). The survey covers all firms with at least 50 employees and 30 million yen of paid-in capital in the Japanese manufacturing, mining, commerce and service sectors. The *Basic Survey of Japanese Business Structure and Activities* contains information on firms' sales, number of employees, book value of tangible fixed assets, wage bill, intermediate materials, R&D, and other indicators.

The data source for Korean firms is the *KIS (Korea Information Service)* Database. The database covers firms subject to statutory audit as well as firms listed on the Korea Stock Exchange. Firms subject to statutory audit are firms with total assets of more than 7 billion Korean Won. Taking the *Business Survey* by the National Statistical Office, which covers most all of firms with 50 or more employees, for reference, the *KIS* data account for more than 70 percent of employees, sales and tangible assets in 2005.

For our comparative analysis, we use the firm-level data for the years 1995 to 2008 for Japan and Korea. Moreover, we restrict our sample to firms with 50 or more employees and 30 million yen (300 million won for Korean firms) or more paid-in capital. For Japan, our dataset includes approximately 26,000–29,000 firms per year, while for Korea the number of observations increases from about 3,500 firms in 1995 to around 8,400 firms in 2008. TFP can be calculated for more than 95 percent of these firms in the case of Japan and for approximately 77 percent in the case of Korea. The total number of observations by industry for the period 1995–2008 is shown in Table 1.[3] As can be seen in the table, in the case of Japan, about half of the firms in the sample are non-manufacturing firms, while in the case of Korea slightly less than 40 percent are non-manufacturing firms. Further, in the case of Japan, more than 70 percent of the non-manufacturing firms fall into the trade sector (wholesale and retail trade), while in the case of Korea, the industry distribution in the non-manufacturing sector is more even. On the other hand, in the manufacturing sector the industry distributions for Japan and Korea look very similar. Given the differences in industry distribution in the non-manufacturing sector and because we are interested in R&D investment and productivity, in the following analysis we focus on manufacturing firms only.

INSERT Table 1

3.2 Productivity Measures for International Comparison

Following Good et al. (1996), firm-level TFP is estimated using the chained-multilateral index number approach. The TFP level of firm *f* in year *t* in a certain industry is defined in comparison with the TFP level of a hypothetical representative firm in the base year (2000) in that industry as follows:

$$\ln TFP_{f,t} = (\ln Q_{f,t} - \overline{\ln Q_t}) - \sum_{i=1}^{n} \frac{1}{2}(S_{i,f,t} + \overline{S_{i,t}})(\ln X_{i,f,t} - \overline{\ln X_{i,t}}) \quad for\ t = 0,$$

and

[3] The number of observations for each year is shown in Appendix Table 1.

$$\ln TFP_{f,t} = (\ln Q_{f,t} - \overline{\ln Q_t}) - \sum_{i=1}^{n} \frac{1}{2}(S_{i,f,t} + \overline{S_{i,t}})(\ln X_{i,f,t} - \overline{\ln X_{i,t}})$$
$$+ \sum_{s=1}^{t} (\overline{\ln Q_s} - \overline{\ln Q_{s-1}}) - \sum_{s=1}^{t} \sum_{i=1}^{n} \frac{1}{2}(\overline{S_{i,s}} + \overline{S_{i,s-1}})(\overline{\ln X_{i,s}} - \overline{\ln X_{i,s-1}})] \ for \ t \geq 1.$$

where $Q_{f,t}$, $S_{i,f,t}$, and $X_{i,f,t}$ denote the gross output of firm *f* in year *t*, the cost share of factor *i* for firm *f* in year *t*, and firm *f*'s input of factor *i* in year *t*, respectively. Variables with an upper bar denote the industry average of that variable in Japan and Korea. The representative firm for each industry is defined as a hypothetical firm whose output, inputs, and cost shares of all production factors are identical to the industry average. More specifically, we first convert values for each variable to internationally-comparable values expressed in a common unit (details of the conversion are provided below). We then pool the firm-level data for Japan and Korea and calculate the hypothetical representative firm's output, inputs, and cost shares.[4] However, as can been seen in the above equations, the TFP index allows for variations of production technology across firms, which is an advantage of this non-parametric method.[5]

The construction of variables to measure TFP is as follows. Real output is defined as total sales deflated using sectoral output deflators derived from the JIP 2011 Database for Japan and deflators from the WIOD (World Input-Output Database, February 2012 Release) for Korea. Nominal intermediate input is calculated as follows:

Intermediate input=Sales costs + Selling & general administrative expenses －Wages － Depreciation

Intermediate inputs are deflated using the intermediate-input deflators provided in the JIP 2011 Database for Japan and the WIOD for Korea. Labor input is defined as the number of employees for each firm. We were not able to take account of differences in labor quality among firms. For capital stock, we computed real capital stock by deflating the book value of tangible fixed assets using investment deflators.[6]

We derived the cost shares of the factors of production as follows. For labor costs, we used

[4] The firm-level data underlying the *BSBSA* were obtained for the research project titled "East Asian Firm-Level Productivity Project" at the Research Institute of Economy, Trade and Industry (RIETI). Although the *BSBSA* data are based on government surveys that are subject to confidentiality restrictions, we were able merge the two datasets, because the *KIS* data are provided by a private company and there are no confidentiality restrictions for the *KIS* data.

[5] Van Biesebroeck (2007) argues that the index number approach tends to be superior to semi-parametric approaches when the measurement errors of the data are small. As our private data source, the *KIS*, may contain more measurement errors than the *BSBSA* data based on government surveys, we drop firms with less than 50 employees and less than 300 million won of paid-in capital and focus on manufacturing firms. We believe that as a result our dataset does not suffer from serious measurement errors. Moreover, in order to check the robustness of our results, we examine various performance measures and do not rely on TFP alone.

[6] While it would be preferable to construct the real capital stock data in a more rigorous manner, we were forced to employ this simple approach due to data constraints for Korean firms.

wage data taken from the *BSBSA* for Japan and from the *KIS* for Korea. Intermediate input costs are defined as nominal intermediate inputs. Capital costs were calculated by multiplying the real net capital stock with the user cost of capital, c_k, i.e.:

$$c_k = \frac{1-z}{1-u} p \left\{ \lambda r + (1-u)(1-\lambda)i + \delta - \left(\frac{\dot{p}}{p} \right) \right\}$$

where u is the effective corporate tax rate, λ is the own-capital ratio, r is the long-term bond rate, i is the prime rate, δ is the depreciation rate, p is the price index, $\dot{p}$ is the five year moving average of the price index, and z is the expected present value of tax savings due to depreciation allowances on a yen (or won) of investment in capital goods. z is calculated as follows:

$$z = (u * \delta) / [\{\lambda r + (1-u)(1-\lambda)i\} + \delta]$$

We measure the cost share of each factor by dividing the costs of each factor by total costs, which is the sum of labor costs, intermediate input costs, and capital costs.

In order to construct an internationally comparable measure of productivity, we convert values in Japanese yen or in Korean won into values in a common unit. We use industry-specific PPP series taken from the ICPA (International Comparison of Productivity among Pan-Pacific Countries) project conducted at RIETI.[7] The ICPA provides industry-specific PPP series for the year 1997, but we converted them to a 2000 basis. Therefore, we first convert all nominal values for output, intermediate input, and capital stock to real values on a 2000 local currency basis. We then convert the real value of output, intermediate input and capital stock of Korean firms into 2000 Japanese yen values using the PPP of the ICPA project. Next, we calculate the internationally comparable TFP index using the real values on a 2000 Japanese yen basis for both Japanese and Korean firms. In addition, we calculate labor productivity (value added per employee) and capital productivity (value added per unit of capital stock), which are also internationally comparable. We also calculate operating margins (ratio of operating profits to sales) and ROA (return on assets: ratio of operating profits to total assets) as other performance measures, although operating margins and ROA are calculated using nominal values.

4. Comparison of Firm Productivity between Japanese Firms and Korean Firms

In this section, we start by looking at trends of various performance measures for Japan and Korea for the period from 1995 to 2008 (Figure 1). As can be seen in panel (a) of Figure 1, the

[7] For details on the ICPA project, see Motohashi (2007).

TFP gap between the two countries does not appear to be shrinking, even though Korean labor productivity has been growing much faster than Japanese labor productivity. This is probably attributable to the low and stagnating capital productivity of Korean firms. Moreover, the TFP figure (panel (a)) suggests that Korean firms are still lagging behind Japanese firms in terms of efficiency of production. The TFP figure also suggests that Korean firms may be overinvesting in tangible fixed assets. On the other hand, Korean firms are superior to Japanese firms in terms of profitability (i.e., operating margins and ROA) throughout the period.

INSERT Figure 1

Looking at the performance measures by industry, the average level of TFP is higher for Japanese firms in the majority of industries, while the average level of ROA is higher for Korean firms in almost all industries. The trends of average TFP and average ROA by industry are shown in Figure 2. As can be seen, the TFP level of Japanese firms tends to be higher and there is no clear convergence between the TFP levels of Japanese and Korean firms in many industries. For example, in the electrical machinery industry, Japanese firms show a much higher TFP level than Korean firms throughout the observation period, which seems to contradict the widespread perception that Korean electronics firms are rapidly gaining on their Japanese counterparts. On the other hand, in the case of the non-electrical machinery industry, the TFP level of Korean firms is higher than that of Japanese firms, although the gap is not very large.

INSERT Figure 2

We conduct a simple OLS regression analysis in order to examine in which industries Korean firms' average TFP level is higher than that of their Japanese counterparts and to examine in which industries Korean firms' TFP is growing. The estimated equations are as follows.

First, to examine whether the average TFP level of Korean firms is higher than that of their Japanese counterparts, we estimate:

$$lnTFP_{ijt}^{C} = \alpha_1 KOR * I_j + \alpha_2 I_j + \alpha_3 T_t + \varepsilon_{ijt}$$

Second, to examine whether Korean firms' average TFP level is growing, we estimate:

$$lnTFP_{ijt}^{C} = \beta_1 KOR * I_j * TR_t + \beta_2 KOR * I_j + \beta_3 I_j + \beta_4 T_t + \varepsilon_{ijt}$$

where subscripts i, j, and t denote the firm, industry, and year, respectively. The superscript c denotes the country, i.e., Japan or Korea. *KOR* is a dummy variable which takes one for Korean firms. I and T denote industry dummies and year dummies, respectively. *TR* is a trend variable which takes one for the first year of the period of analysis, i.e., 1995, and increases by one every year. ε is an error term. If the estimated coefficient α_I is positive and significant, this is interpreted as implying that Korean firms' average TFP level is higher than that of their Japanese counterparts. If the estimated coefficient β_I is positive and significant, this is interpreted as implying that Korean firms' average TFP level is growing faster than that of their Japanese counterparts. The estimated coefficients α_I and β_I for each industry are shown in Table 2.

According to the results shown in Table 2, Korean average TFP is higher in only five out of the twenty manufacturing industries. The five industries are food and kindred products, furniture and fixtures, petroleum and coal products, fabricated metal, and non-electrical machinery. Further, although Korean TFP is growing in eight out of the twenty manufacturing industries, the average TFP level of Korean firms has not yet reached that of their Japanese counterparts in seven out of those eight industries. Therefore, in terms of production efficiency, Korean firms have not yet reached the level of Japanese firms in the majority of manufacturing industries.

INSERT Table 2

5. Comparison of R&D Intensity between Japanese and Korean Firms

In the previous section, we found that Japanese firms seem to be superior in terms of their TFP level in most industries. However, as mentioned in the introduction, Korea has been rapidly increasing R&D expenditures at the macro level, which is expected to advance technological capabilities in Korea. In this section, we look at the R&D activities of Japanese and Korean manufacturing firms in greater detail.

We start by looking at the number of R&D-performing firms in Japan and Korea, which is shown in Table 3. On average, 45 percent of firms in Japan invest in R&D activities, while the corresponding share for firms in Korea is 60 percent.

INSERT Table 3

As for the R&D intensity (ratio of R&D expenditure to sales), the average intensity is slightly higher for Korean firms, but the distribution of R&D intensity is more skewed (Table

4).[8] Moreover, as shown in Figure 3, the average R&D intensity in Korea has been increasing over time, while it has been quite stable in Japan.[9] On the other hand, when looking at balanced panel data for Korean firms, the increase in the average R&D intensity is much more moderate. This finding suggests that the increase in the overall average R&D intensity for Korean firms is mainly accounted for by the entry of firms with a high R&D intensity and not an increase in the R&D intensity of "old" firms that are included in the database from the initial year.

INSERT Table 4 and Figure 3

Next, Figure 4 shows the cumulative output shares and cumulative R&D expenditure shares for Japan and Korea for the years 1995, 2000, 2005, and 2008. For each year and country, we first calculate the output share and the R&D expenditure share of each firm. We then sort firms by output share in ascending order and calculate the cumulative output share and the cumulative R&D expenditure share. If the resulting curve is concave, this can be interpreted as indicating that larger firms spend disproportionately more on R&D. Moreover the more concave the curve is, the more disproportionately larger firms spend on R&D. In Figure 4, the thickest lines show the relationship for 2008, while the thinnest lines show the relationship for 1995, with the solid lines showing the relationship for Japan and the dotted lines showing that for Korea. Focusing on Korea first, Figure 4 shows that in 1995 and 2000 R&D activities were more concentrated in larger firms (as measured by their sales share), but smaller firms have been increasing their R&D spending in recent years (2005 and 2008).[10] On the other hand, in Japan, it is actually larger firms whose R&D expenditure has been increasing rather than that of smaller firms, although the shift is not as drastic as that in Korea in the opposite direction.[11] Together with the trend in Figure 3, the figure implies that in recent years it has been smaller firms that have newly entered the market that have a relatively high R&D intensity in Korea.

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[8] There are a lot of Korean firms with an R&D intensity above one (i.e., their R&D expenditures exceed their sales), which clearly does not seem to be plausible. Therefore, in order to calculate the figures for Table 4, we first dropped observations for which the R&D intensity exceeded one and then excluded observations for which the R&D intensity is higher than the 99th percentile of the R&D intensity distribution for each country and year.

[9] Summary statistics of the R&D intensity for Japan and Korea for each year are provided in Appendix Table 2.

[10] A couple of papers also mention that until the 1997 Asian crisis, R&D activities were largely led by large-scale firms. After the crisis, R&D activities by small and medium-sized firms increased significantly, while R&D investment by large firms rose only at a low rate (Oh et al. 2009, Heshmati and Kim 2011).

[11] Appendix Table 3 provides a summary of various characteristics of Japanese and Korean firms. The table suggests that R&D-performing firms in Japan tend to be much larger than the average Japanese firm, while R&D-performing firms in Korea are only slightly larger than the average Korean firm. The table thus also indicates that small firms in Korea are more likely to perform R&D activities than their Japanese counterparts.

INSERT Figure 4

Looking at the average R&D intensity by industry, which is shown in Table 5, this indicates that Japan has a much higher average R&D intensity in most manufacturing industries, which contrasts with the result in Table 4 above suggesting that the average R&D intensity for manufacturing as a whole is slightly higher in Korea than in Japan. A possible explanation for this seeming contradiction is that manufacturing activity in Korea is concentrated in industries with a higher average R&D intensity, resulting in a higher average R&D intensity overall.

INSERT Table 5

6. R&D Investment and Productivity

So far, we have found that Korean firms' TFP level has not yet caught up with the TFP level of Japanese firms on average, although Korean firms are superior to Japanese firms in terms of labor productivity and profitability. On the other hand, Korean firms, particularly smaller firms have been increasing their R&D spending, and the average R&D intensity of Korean firms has been increasing over time, while the average R&D intensity of Japanese firms has been quite stable.

Why has Korean firms' TFP level not been catching up with that of their Japanese counterparts even though Korean firms have been becoming more R&D intensive? One possible explanation is that Korean firms overinvest in R&D activities and their R&D activities are less efficient than those of Japanese firms. In this section, we examine the rate of return on R&D investment for Korean firms in comparison to that for Japanese firms.

In fact, there are many empirical studies which calculate the rate of return on R&D in developed countries, including Japan. Following several previous studies, such as Goto and Suzuki (1989), Griliches and Mairesse (1990), and Wakelin (2001), we directly estimate the rate of return on R&D investment in the following way.[12] We use the firm-level TFP as a productivity measure and regress the TFP growth rate on R&D intensity. Specifically, the regression equation we estimate is as follows:

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[12] The rate of return on R&D can be estimated using the production function approach, and this approach has been widely employed in previous studies. However, problems with this approach include measurement errors in the estimation of R&D stock, endogeneity among variables in the production function, and so on. Bond et al. (2003) address the endogeneity problem by using the system GMM estimation method. However, measurement problems with regard to the R&D stock are difficult to resolve. Given the relatively low quality of data on Korean firms, we do not employ the production function approach in this paper.

$$\Delta \ln \text{TFP}_{it} = \alpha RDINT_{it} + \beta RDINT_{it} * KOR_i + \theta_i + \tau_t + \varepsilon_{it},$$

where $\Delta lnTFP$ denotes the TFP growth rate and *RDINT* is the R&D intensity measured as the ratio of R&D expenditures to sales. *KOR* is a dummy variable which takes one for Korean firms. Subscripts i and t denote the firm and year, respectively. θ and τ capture firm-specific fixed effects and year-specific effects, respectively. ε is an error term. We also estimate the same equation for firms in each country separately. In this case, we exclude the cross term of *RDINT* and *KOR*. The estimated coefficient α ($\alpha+\beta$ for Korean firms) represents the rate of return on R&D investment.

The results of the fixed-effect panel estimation are summarized in Table 6. Column (1) in each panel shows the estimation results for all firms. For columns (2) to (5), we divide our sample firms into four groups depending on firms' TFP level. Specifically, for each industry and each year, we classify firms into one of four groups, namely, the lowest 25 percent, the 25th-50th percentile, the 50th-75th percentile, and the top 25 percent in the TFP distribution. The TFP distribution is not considered separately for Korea and Japan; instead, we pool all the data and calculate the TFP distribution by industry and year. For columns (6) to (8), we divide our sample firms into three groups depending on firm size measured by the number of employees.

Starting with the results in column (1) of each of the panels, the estimated rate of return on R&D ranges from 27 percent to 35 percent. This is roughly consistent with estimates in previous studies on Japan and European countries, where the rate of return on R&D is estimated to be around 22-27 percent.[13] Further, looking at the results in the different panels, we find that in the pooled regression (panel (a)) the rate of return on R&D for Korea is not significantly higher than that for Japan, while in the separate regressions in panels (b) and (c) the average rate of return of Korean firms (35 percent) is higher than that of Japanese firms (27%). Next, looking at the estimated rate of return when firms are grouped in terms of their productivity, we find that the rate of return of firms that fall into the top 25 percent is significantly higher in Korea than in Japan (column (5) in panel (a)). Moreover, columns (2)-(5) in panels (b) and (c) show that the gap in the rate of return between Korean and Japanese firms is largest for firms in the highest productivity group, although the rate of return tends to be higher for Korean firms in all productivity groups. Next, looking at the rate of return when grouping firms in terms of their size, we find that the rate of return of large Korean firms is significantly higher than that of Japanese firms; on the other hand, the rate of return of small firms in Korea is almost the same as that of small firms in Japan (columns (6)-(8)). In addition, we find that in Japan, the

[13] The results in previous related studies are summarized in Inui and Kwon (2005).

estimated rate of return is highest for small firms and lowest for medium-sized firms, which is consistent with estimates by Inui and Kwon (2005).

To summarize, the results suggest that although we find the rate of return on R&D to be generally higher for Korean firms, the difference, when looking at all firms, is not statistically significant. Generally speaking, one would expect the rate of return to be higher in lagging than in leading countries, because firms in the former have a lower level of productivity and therefore have more to gain by engaging in R&D activities. Given that Korean firms' TFP tends to be lower than that of their Japanese counterparts, our results therefore suggest that the rate of return on R&D of the former is not sufficiently high.

Moreover, given that interest rates are much higher in Korea than in Japan, the result also implies that Korean firms need a higher rate of return in order to cover the larger interest payments. However, comparing the rate of return for small firms in both countries, the rate of return in Korea is not significantly higher than that in Japan. Particularly for smaller Korean firms, the rate of return on R&D seems low when compared to Japanese firms and larger Korean firms, even though smaller firms are more likely to face financial constraints and higher interest rates. Again, the results suggest that particularly for smaller firms, the rate of return on R&D for Korean firms may be too low to cover the larger interest payments.

However, we should note that for firms in the highest productivity group and for large firms, the rate of return in Korea is much higher than that in Japan. This raises the interesting question why the rate of return on R&D is so low for large and/or highly productive firms in Japan and so high for large and/or highly productive firms in Korea. Unfortunately, it is beyond the scope of this paper to address this question. On the other hand, the rate of return of small firms in Korea is relatively low, while that of small firms in Japan is relatively high. One possible reason is differences in tax incentives between the two countries. According to OECD (2010), tax incentives tend to be more generous for smaller firms in Korea, while they tend to be more generous for larger firms in Japan.[14] The more generous tax incentives may have promoted R&D investments by smaller firms in Korea and may explain why their rate of return on R&D is relatively low. Another possible reason is weak technology spillovers from large and/or highly productive firms to small and/or less productive firms in Korea. Examining this hypothesis is beyond the scope of the present paper but is an interesting topic left for closer scrutiny in future

[14] According to OECD (2010), the volume-based tax credit rate for large firms in Korea is only 3-6 percent, while small firms enjoy a rate of 25 percent, and the tax credit rate on incremental R&D expenditures, including R&D wages, for small firms is 50 percent. On the other hand, the R&D tax credit in Japan is 12 percent on volume for small and medium-sized firms and 8-10 percent for large firms, and 5 percent on incremental R&D. While international comparisons of tax incentives are not straightforward because of the complexities of the tax system of each country, these figures suggest that the Korean government seems to provide more generous R&D tax incentives for small firms than the Japanese government.

investigations. The result also suggests that small and/or less productive firms in Korea may lack sufficient R&D management know-how or human capital that is complementary to R&D investment and necessary for improving the efficiency of R&D investment. The low rate of return on R&D for small firms in Korea thus may be due to a lack of intra-firm spillovers and complementary capabilities, meaning that such firms require a large amount of R&D investment in order to obtain a certain amount of return from the investment.

As mentioned above, the difference in the rate of return between Korea and Japan is very large for large and/or highly productive firms. This is an issue that certainly requires further investigation, but it may be related to differences in corporate governance, technology management, financial constraints, intra- and/or inter-firm technology spillovers, technology spillovers from public research institutes, and so on.

INSERT Table 6

7. Concluding Remarks

In this paper, we investigated differences in the performance and R&D activities of Japanese and Korean firms using a large-scale firm-level dataset for the period from 1995 to 2008. More specifically, using industry-specific PPP rates, we constructed a firm-level TFP measure that allows international comparisons.

Despite the fact that some Korean firms have been gaining large global market shares in recent years, we find that the majority of Korean firms are still lagged behind Japanese firms in terms of their TFP level, resulting in low average TFP for Korean firms overall. Moreover, although Korean firms' TFP seems to be catching up with that of their Japanese counterparts in some industries, there remains a significant gap in the average TFP level of firms in the two countries. Based on our analysis, the low TFP levels of Korean firms may be partly explained by the low and stagnating capital productivity of Korean firms, which suggests that Korean firms overinvest in tangible fixed assets. On the other hand, average labor productivity and profitability is higher for Korean firms than for their Japanese counterparts.

In order to further investigate the factors underlying the TFP gap between the two countries, we examined the distribution of R&D activities among firms and estimated the rate of return on R&D investment for Korean and Japanese firms. We found that in recent years, smaller firms have been increasing their R&D spending more rapidly than larger firms in Korea, while the opposite tendency is observed in Japan. Partly reflecting the aggressive R&D investment by smaller firms in Korea, their estimated rate of return on R&D is relatively low, while the rate of return for large firms is very high. On the other hand, in Japan the estimated rate of return is higher for smaller firms than for larger firms, and the rate of return for large firms is much lower than that for Korean firms.

The low rate of return on R&D for small Korean firms likely partly explains the persistent TFP gap between Korean and Japanese firms. Differences in R&D tax incentives between the two countries may be a possible reason why small Korean firms have been expanding their R&D spending aggressively despite the low rates of return. Another possible factor is the strength of inter-firm and/or intra-firm technology spillovers, which may determine the rate of return on R&D, and such spillovers may be weak for small firms in Korea. On the other hand, the relatively low rate of return on R&D for large firms in Japan may partly explain the declining market penetration of some major Japanese firms. Exploring the factors determining the rate of return on R&D is beyond scope of this paper and is left for closer scrutiny in future investigations.

Another important issue to be investigated in future studies is the relationship between the reallocation of R&D activities among firms and aggregate productivity growth. Lentz and Mortensen (2008), for example, find that in their panel dataset of Danish firms 53 percent of aggregate productivity growth is explained by worker reallocation to firms of better innovation capacity. Such an analysis for Korea and Japan could provide important empirical evidence especially for policy makers who need to design effective policy schemes for R&D promotion.

While there still remain a lot of issues to be addressed in future studies, the results of this paper provide important policy implications for both Korea and Japan. For Korea, investigating how to improve the R&D efficiency of smaller firms appears to be an urgent task for researchers and policy makers. Probably owing to the generous tax incentives, small firms in Korea have been increasing their R&D spending. The next step now is to help create an environment in which technological information is smoothly exchanged among firms or between firms and research institutes and to help small firms accumulate R&D management know-how and human capital. For Japan, although the majority of Korean firms are still lagging behind Japanese firms in terms of TFP and at this point in time the rate of return on R&D for Korean firms is not yet significantly higher than that for Japanese firms, Korean firms, particularly smaller firms, may be able to raise their technology level drastically in the near future once their R&D activities gain traction. Against this background, expanding R&D tax incentives particularly for promising smaller firms would be one policy option in order to promote R&D activities by smaller firms. On the other hand, the rate of return on R&D of larger firms in Japan is relatively low. While further investigations are required, there is scope for various policy support measures to improve the R&D efficiency of such firms, such as promoting international cooperative R&D activities, academic-industrial alliances, and so on. Particularly for large firms competing in global markets, world-wide management of their R&D activities is necessary, and in this area, there is a lot the government can do, such as negotiating international rules for trade and investment and intellectual property rights, promoting government-funded international joint research projects, supporting international research exchange, etc., all of which should contribute to improving the R&D efficiency for larger firms in Japan.

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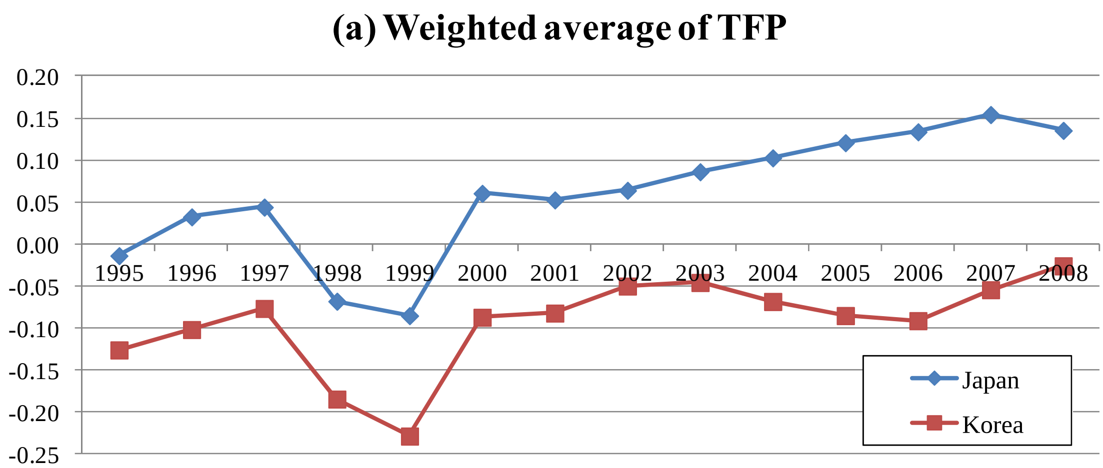
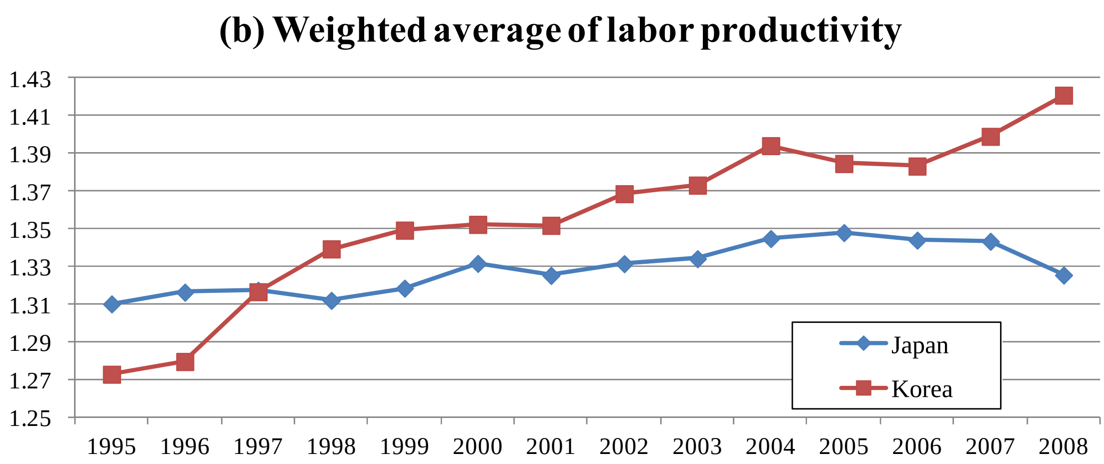
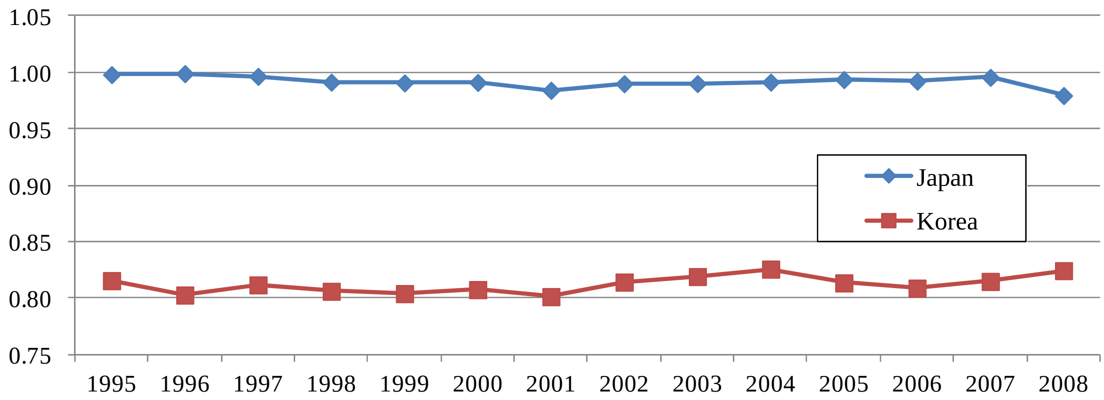
Figures and Tables

Figure 1. Comparison of performance measures for Japanese and Korean manufacturing firms

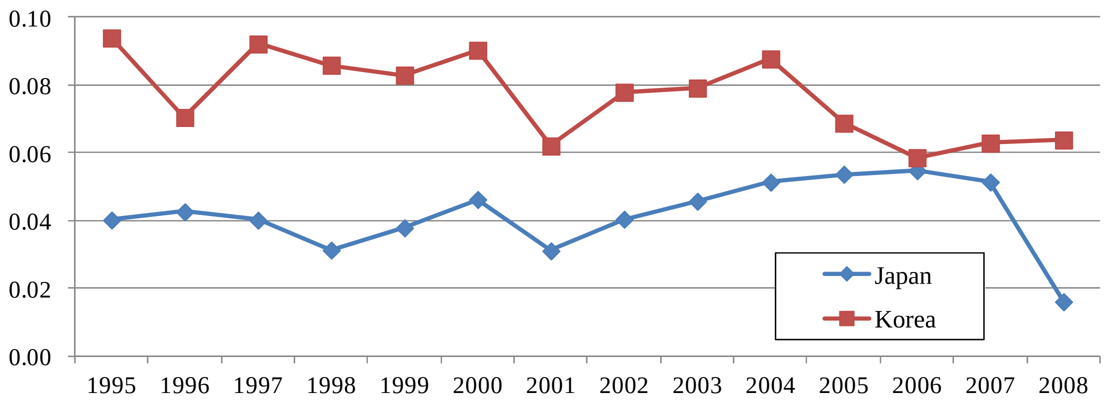




(c) Weighted average of capital productivity

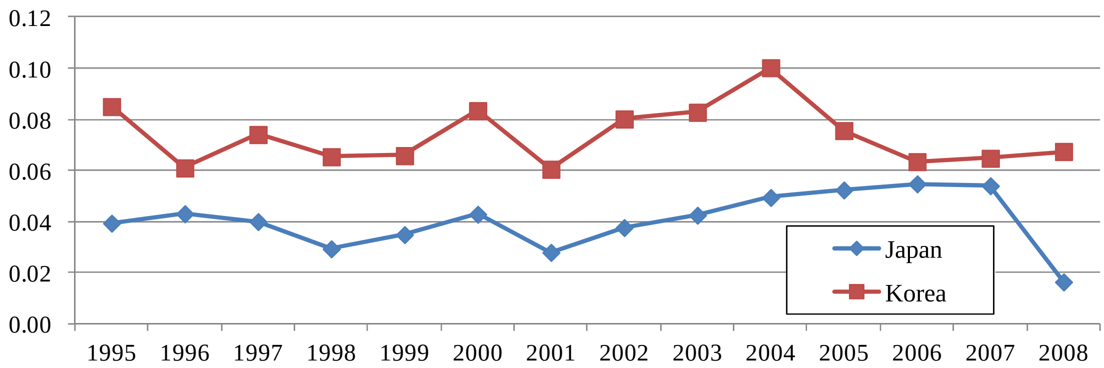


(d) Weighted average of operating margin



(e) Weighted average of return on assets (ROA)

(Manufacturing firms with 50+ employees and 30+ mil. yen capital)



Note: The weighted average of each performance measure is calculated for manufacturing firms with 50 or more employees and 30 million yen (300 million won for Korean firms) of paid-in capital using the sales share as weight.

Figure 2. Performance measures by industry

(a) Weighted average of lnTFP by industry

(b) Weighted average of ROA by industry

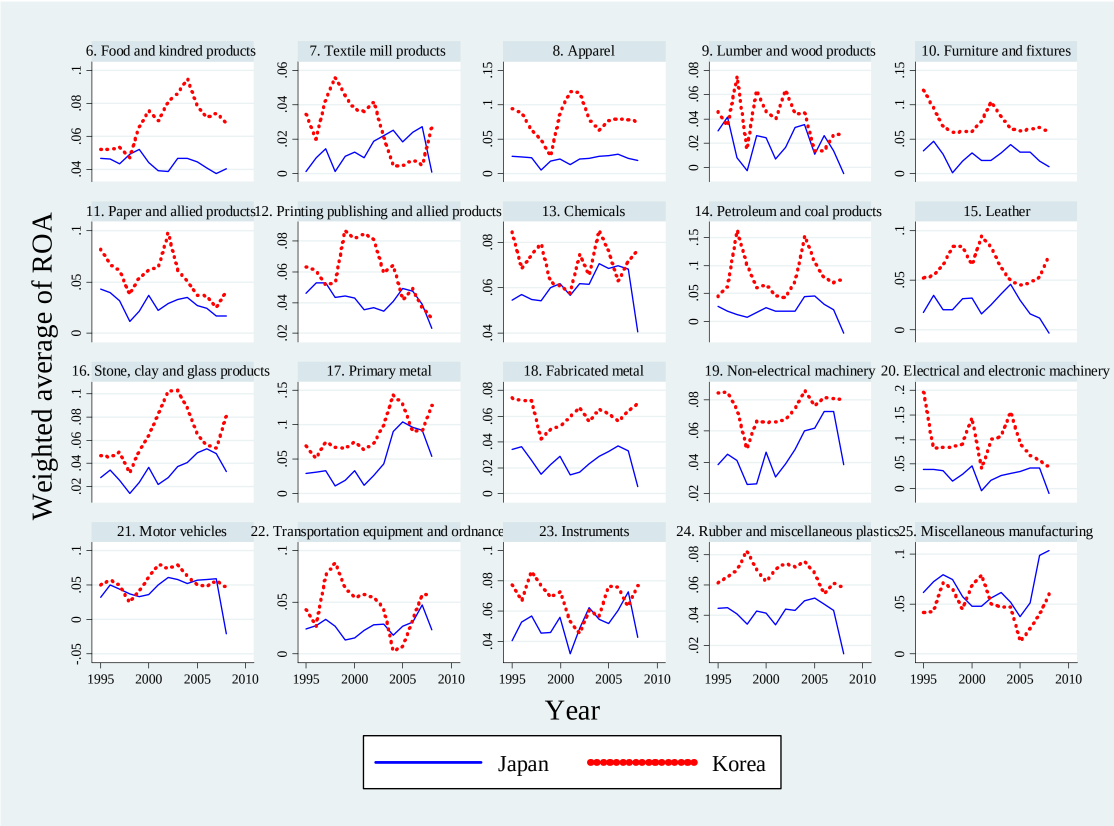
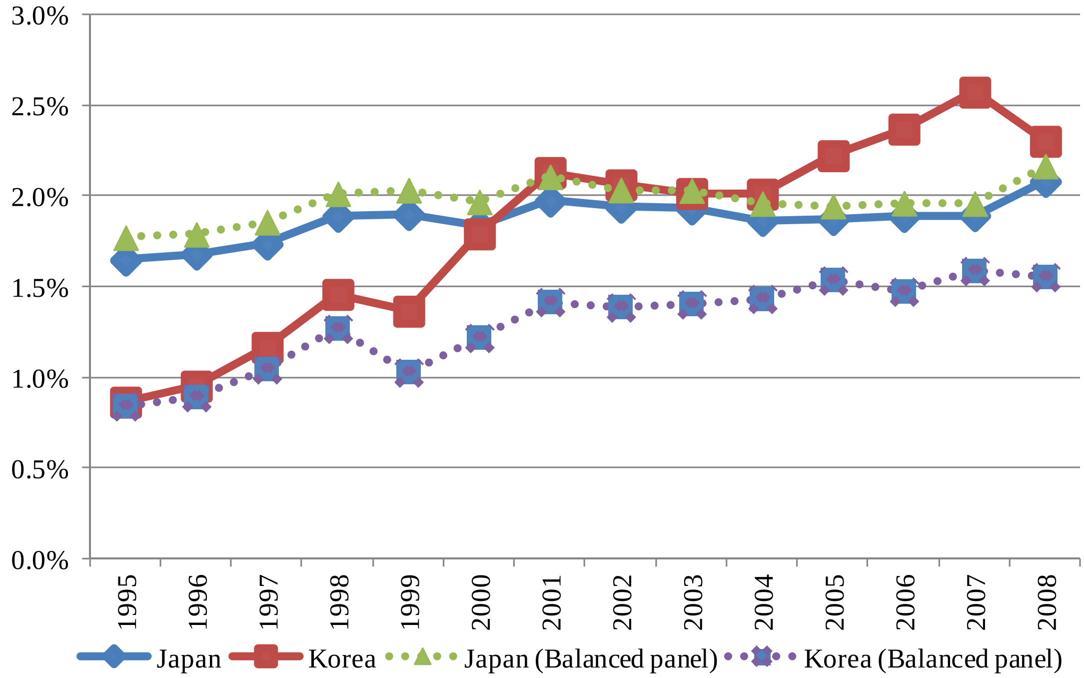
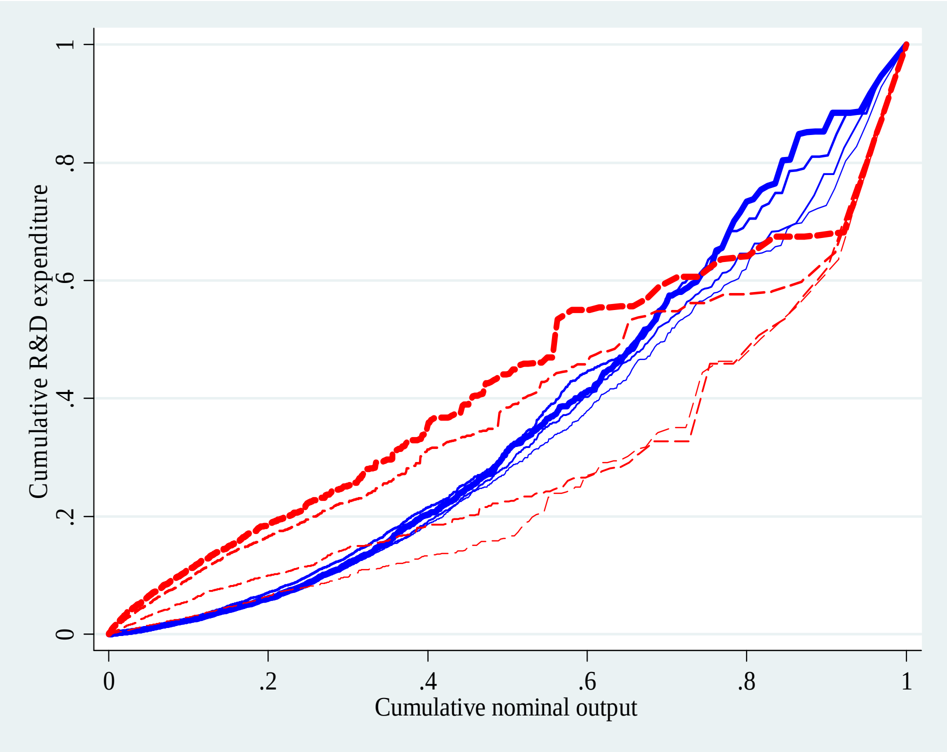


Figure 3. Average R&D intensity (R&D expenditure / Sales)



Note: Observations with a higher R&D intensity than the 99th percentile value for each country and year or with an R&D intensity exceeding one are excluded.

Figure 4. Cumulative output and cumulative R&D expenditure for Japan and Korea: 1995, 2000, 2005, and 2008



Notes: The solid lines are for Japan, while the dotted lines are for Korea.

The thickest lines are for the year 2008, and the thinnest lines are for the year 1995.

The thicker the line is, the more recent the year the line represents.

Table 1. Total number of observations in the database by industry (1995 - 2008)

Industry		Whole sample		TFP-calculated			
		Japan	Korea	Japan	Share (%)	Korea	Share (%)
6	Food and kindred products	22,926	3,576	22,453	(12.03)	3,029	(6.00)
7	Textile mill products	4,660	2,434	4,579	(2.45)	2,130	(4.22)
8	Apparel	5,098	2,233	4,955	(2.65)	1,873	(3.71)
9	Lumber and wood products	2,193	271	2,142	(1.15)	230	(0.46)
10	Furniture and fixtures	2,343	450	2,292	(1.23)	395	(0.78)
11	Paper and allied products	5,932	1,494	5,821	(3.12)	1,268	(2.51)
12	Printing publishing and allied products	11,534	670	11,287	(6.05)	452	(0.90)
13	Chemicals	13,154	6,252	12,990	(6.96)	5,580	(11.05)
14	Petroleum and coal products	753	266	745	(0.40)	229	(0.45)
15	Leather	522	638	501	(0.27)	585	(1.16)
16	Stone, clay and glass products	7,601	2,414	7,435	(3.98)	2,032	(4.03)
17	Primary metal	6,584	3,747	6,517	(3.49)	3,183	(6.31)
18	Fabricated metal	17,736	3,305	17,410	(9.33)	2,660	(5.27)
19	Non-electrical machinery	22,898	6,396	22,487	(12.05)	5,426	(10.75)
20	Electrical and electronic machinery	28,210	11,206	27,766	(14.88)	9,827	(19.47)
21	Motor vehicles	13,072	6,595	12,970	(6.95)	5,882	(11.65)
22	Transportation equipment and ordnance	3,326	1,171	3,271	(1.75)	963	(1.91)
23	Instruments	5,083	1,692	5,028	(2.69)	1,441	(2.85)
24	Rubber and miscellaneous plastics	11,932	3,275	11,729	(6.28)	2,745	(5.44)
25	Miscellaneous manufacturing	4,315	671	4,260	(2.28)	551	(1.09)
	Manufacturing total	189,872	58,756	186,638	(100.00)	50,481	(100.00)
1	Agriculture	185	400	183	(0.10)	342	(1.48)
2	Coal mining	705	64	697	(0.37)	43	(0.19)
3	Metal and nonmetallic mining		171			151	(0.65)
4	Oil and gas extraction		2				
5	Construction	6,085	7,710	6,026	(3.22)	5,367	(23.16)
26	Transportation	1,515	3,372	1,484	(0.79)	2,583	(11.15)
27	Communications	457	5,998	448	(0.24)	4,835	(20.87)
28	Electrical utilities	347	533	342	(0.18)	432	(1.86)
29	Gas utilities	1,097		1,051	(0.56)		
30	Trade	137,963	8,294	135,938	(72.67)	3,247	(14.01)
31	Finance, insurance, and real estate	1,521	2,374	1,435	(0.77)	716	(3.09)
32	Other private services	42,727	2,779	39,455	(21.09)	2,260	(9.75)
33	Public service	15	4,630	13	(0.01)	3,195	(13.79)
	Non-manufacturing total	192,617	36,327	187,072	(100.00)	23,171	(100.00)
	Total	382,489	95,083	373,710		73,652	

Note: Firms with 50 or more employees and 30 million yen (300 million won for Korea) of paid-in capital.

Table 2. TFP comparison between Japan and Korea by industry

Industry	Coefficient on Korea dummy (α_1)		Coefficient on Korea dummy × TR (β_1)	
	Coef.	Country with higher productivity	Coef.	Korean TFP growing
1 Agriculture	*0.13* ***	*Korea*	-0.014 ***	
2 Coal mining	-1.32 ***	Japan	-0.022 *	
3 Metal and nonmetallic mining	*0.14* ***	*Korea*	-0.014 **	
5 Construction	*0.18* ***	*Korea*	-0.016 ***	
6 Food and kindred products	*0.15* ***	*Korea*	-0.002 ***	
7 Textile mill products	-0.15 ***	Japan	*0.010* ***	*O*
8 Apparel	-0.29 ***	Japan	*0.019* ***	*O*
9 Lumber and wood products	0.01		-0.009	
10 Furniture and fixtures	*0.18* ***	*Korea*	*0.003* ***	*O*
11 Paper and allied products	-0.27 ***	Japan	-0.006 ***	
12 Printing publishing and allied products	-0.25 ***	Japan	-0.005 ***	
13 Chemicals	-0.09 ***	Japan	*0.001* **	*O*
14 Petroleum and coal products	*0.54* ***	*Korea*	-0.053 ***	
15 Leather	0.00		0.020	
16 Stone, clay and glass products	-0.13 ***	Japan	*0.011* ***	*O*
17 Primary metal	-0.21 ***	Japan	-0.011 ***	
18 Fabricated metal	*0.12* ***	*Korea*	-0.016 ***	
19 Non-electricalmachinery	*0.11* ***	*Korea*	-0.001 **	
20 Electrical and electronic machinery	-0.29 ***	Japan	*0.034* ***	*O*
21 Motor vehicles	-0.17 ***	Japan	*0.008* ***	*O*
22 Transportation equipment and ordnance	-0.04 ***	Japan	0.000	
23 Instruments	-0.32 ***	Japan	*0.035* ***	*O*
24 Rubber and miscellaneous plastics	-0.17 ***	Japan	-0.007 ***	
25 Miscellaneous manufacturing	-0.19 ***	Japan	-0.021 ***	
26 Transportation	-0.05 ***	Japan	*0.005* ***	*O*
27 Communications	0.30 ***		*0.008* ***	*O*
28 Electrical utilities	-0.26 ***	Japan	*0.139* ***	*O*
30 Trade	-0.19 ***	Japan	-0.011 ***	
31 Finance, insurance, and real estate	-0.29 ***	Japan	-0.008 *	
32 Other private services	*0.16* ***	*Korea*	-0.049 ***	
33 Public service	-0.02		-0.092	

Note: ***, **, and * indicate statistical significance at the 1, 5, and 10 percent level, respectively.

Table 3. Number of R&D performing firms

Year	Japan	R&D performing	(%)	Korea	R&D performing	(%)
Manufacturing sector						
1995	14,342	6,635	(46)	2,276	1,414	(62)
1996	14,204	6,415	(45)	2,417	1,503	(62)
1997	14,073	6,287	(45)	2,650	1,600	(60)
1998	14,039	6,241	(44)	2,842	1,676	(59)
1999	13,823	6,253	(45)	3,616	1,937	(54)
2000	13,460	6,005	(45)	4,142	2,319	(56)
2001	13,453	6,144	(46)	4,584	2,597	(57)
2002	13,138	6,016	(46)	4,729	2,742	(58)
2003	12,630	5,723	(45)	4,848	2,884	(59)
2004	13,442	6,131	(46)	5,024	3,066	(61)
2005	13,170	6,061	(46)	5,316	3,231	(61)
2006	12,937	5,764	(45)	5,557	3,434	(62)
2007	13,549	5,806	(43)	5,914	3,706	(63)
2008	13,612	5,811	(43)	4,841	3,120	(64)
Total	189,872	85,292	(45)	58,756	35,229	(60)

Table 4. Average R&D intensity for Japan and Korea

Country	Obs.	Mean	SD	Min.	Median	Max.	Skewness
Japan	84,434	0.019	0.023	9.49E-06	0.010	0.179	2.051
Korea	34,860	0.020	0.030	3.91E-09	0.008	0.346	3.253
Total	119,294	0.019	0.025	3.91E-09	0.009	0.346	2.732

Note: Observations with a higher R&D intensity than the 99th percentile value for each country and year or with an R&D intensity exceeding one are excluded.

Table 5. Average R&D intensity for Japan and Korea by industry

Industry	Japan	Korea
6. Food and kindred products	0.009	0.003
7. Textile mill products	0.016	0.003
8. Apparel	0.003	0.002
9. Lumber and wood products	0.002	0.002
10. Furniture and fixtures	0.008	0.004
11. Paper and allied products	0.006	0.002
12. Printing publishing and allied products	0.005	0.001
13. Chemicals	0.052	0.010
14. Petroleum and coal products	0.002	0.000
15. Leather	0.007	0.007
16. Stone, clay and glass products	0.014	0.006
17. Primary metal	0.012	0.005
18. Fabricated metal	0.014	0.008
19. Non-electrical machinery	0.037	0.015
20. Electrical and electronic machinery	0.049	0.038
21. Motor vehicles	0.037	0.018
22. Transportation equipment and ordnance	0.013	0.014
23. Instruments	0.036	0.039
24. Rubber and miscellaneous plastics	0.021	0.010
25. Miscellaneous manufacturing	0.022	0.007

Note: Larger values are shaded in gray.

Table 6. Fixed effect estimation results

(a) Pooled sample

	All firms (1)	Lowest productivity (2)	Lower-middle productivity (3)	Upper middle productivity (4)	Highest productivity (5)	Small (50 - 299 workers) (6)	Medium (300-999 workers) (7)	Large (1000-workers) (8)
RDINT	0.283 ***	0.358 **	0.327 ***	0.388 ***	0.316 ***	0.333 ***	0.217 ***	0.257 ***
	[9.416]	[2.389]	[4.844]	[8.212]	[7.655]	[8.010]	[3.917]	[4.020]
RDINT*KOR	0.037	-0.035	0.098	0.075	0.175 *	-0.013	0.171	0.425 **
	[0.829]	[-0.222]	[0.922]	[0.650]	[1.842]	[-0.230]	[1.389]	[2.493]
No. of obs.	93,446	20,774	20,641	23,593	28,438	61,857	22,311	9,278
No. of groups	15,868	6,177	7,745	7,870	6,821	12,494	3,944	1,360
F value	101.660 ***	12.640 ***	20.240 ***	41.880 ***	52.430 ***	49.580 ***	40.570 ***	30.420 ***
R-squared	0.042	0.026	0.048	0.081	0.074	0.032	0.068	0.1037

(b) Japan

	All firms (1)	Lowest productivity (2)	Lower-middle productivity (3)	Upper middle productivity (4)	Highest productivity (5)	Small (50 - 299 workers) (6)	Medium (300-999 workers) (7)	Large (1000-workers) (8)
RDINT	0.273 ***	0.333 **	0.319 ***	0.386 ***	0.303 ***	0.325 ***	0.206 ***	0.255 ***
	[10.065]	[2.487]	[5.039]	[8.476]	[7.720]	[8.619]	[3.988]	[4.226]
No. of obs.	67,117	7,148	15,203	21,413	23,353	41,406	17,849	7,862
No. of groups	11,283	2,943	5,694	6,878	5,573	8,360	3,106	1,118
F value	140.350 ***	8.160 ***	25.000 ***	48.750 ***	65.910 ***	68.620 ***	51.480 ***	34.650 ***
R-squared	0.075	0.055	0.076	0.097	0.106	0.062	0.101	0.130

(c) Korea

	All firms (1)	Lowest productivity (2)	Lower-middle productivity (3)	Upper middle productivity (4)	Highest productivity (5)	Small (50 - 299 workers) (6)	Medium (300-999 workers) (7)	Large (1000-workers) (8)
RDINT	0.348 ***	0.338 ***	0.500 ***	0.481 ***	0.507 ***	0.349 ***	0.450 ***	0.670 ***
	[8.864]	[6.305]	[5.440]	[3.381]	[4.997]	[8.021]	[3.346]	[3.382]
No. of obs.	26,329	13,626	5,438	2,180	5,085	20,451	4,462	1,416
No. of groups	4,585	3,234	2,051	992	1,248	4,134	838	242
F value	35.060 ***	25.290 ***	15.350 ***	3.240 ***	6.730 ***	21.800 ***	10.790 ***	7.050 ***
R-squared	0.021	0.031	0.056	0.035	0.022	0.017	0.037	0.073

Notes: * $p<0.10$, ** $p<0.05$, *** $p<0.01$.

t-values are shown in brackets. Constants, year dummies, and industry dummies are suppressed.

Appendix Table 1. Number of firms in the database

Year	Whole sample		TFP calculated	
	Japan	Korea	Japan	Korea
1995	26,385	3,527	26,223	3,013
1996	26,268	3,709	26,082	3,227
1997	26,206	4,065	26,083	3,568
1998	26,202	4,423	26,097	3,634
1999	25,770	5,721	25,672	4,203
2000	27,587	6,621	26,544	4,630
2001	28,106	7,416	27,342	5,215
2002	27,494	7,821	26,728	5,725
2003	26,565	7,900	25,940	6,244
2004	28,241	8,149	27,326	6,483
2005	27,585	8,674	26,950	6,821
2006	27,782	9,108	26,759	7,097
2007	28,995	10,524	27,881	7,085
2008	29,303	8,404	28,083	6,707
Total	382,489	96,062	373,710	73,652

Notes: All industries. Firms with 50 or more employees and 30 million yen (300 million won for Korea) of paid-in capital.

Appendix Table 2. R&D intensity for Japanese and Korean firms

Panel (a) Japanese firms, all R&D performing firms with 50 or more employees and 30 million yen or more of paid-in capital

Year	Obs.	Mean	SD	Min.	Median	Max.	Skewness
1995	6,564	0.016	0.020	3.45E-05	0.009	0.109	1.900
1996	6,345	0.017	0.020	1.49E-05	0.009	0.113	1.914
1997	6,221	0.017	0.020	1.70E-05	0.010	0.114	1.853
1998	6,170	0.019	0.023	1.61E-05	0.010	0.130	1.865
1999	6,183	0.019	0.022	1.60E-05	0.010	0.120	1.770
2000	5,946	0.018	0.022	1.60E-05	0.010	0.122	1.863
2001	6,084	0.020	0.024	1.58E-05	0.010	0.142	2.001
2002	5,959	0.019	0.024	1.75E-05	0.010	0.135	1.994
2003	5,663	0.019	0.023	2.65E-05	0.010	0.140	1.982
2004	6,065	0.019	0.023	2.20E-05	0.010	0.132	1.940
2005	6,003	0.019	0.023	1.84E-05	0.009	0.136	2.029
2006	5,716	0.019	0.024	1.47E-05	0.009	0.147	2.146
2007	5,752	0.019	0.024	2.77E-05	0.009	0.152	2.162
2008	5,763	0.021	0.028	9.49E-06	0.010	0.179	2.351
Total	84,434	0.019	0.023	9.49E-06	0.010	0.179	2.051

Panel (b) Korean firms, all R&D performing firms with 50 or more employees and 300 million won or more of paid-in capital

Year	Obs.	Mean	SD	Min.	Median	Max.	Skewness
1995	1,404	0.009	0.014	1.00E-08	0.003	0.092	2.878
1996	1,492	0.010	0.014	3.91E-09	0.004	0.101	2.834
1997	1,586	0.012	0.017	3.14E-08	0.005	0.125	2.725
1998	1,661	0.015	0.022	1.02E-08	0.006	0.193	2.995
1999	1,921	0.014	0.021	9.36E-08	0.005	0.174	3.110
2000	2,291	0.018	0.030	3.60E-08	0.007	0.261	3.515
2001	2,563	0.021	0.037	4.12E-08	0.008	0.346	4.079
2002	2,709	0.021	0.034	1.30E-08	0.008	0.262	3.449
2003	2,853	0.020	0.029	2.09E-08	0.009	0.222	2.784
2004	3,036	0.020	0.029	3.01E-08	0.009	0.203	2.686
2005	3,199	0.022	0.031	6.63E-09	0.010	0.240	2.629
2006	3,393	0.024	0.033	4.96E-09	0.012	0.265	2.722
2007	3,662	0.026	0.037	4.00E-08	0.012	0.267	2.699
2008	3,090	0.023	0.032	9.42E-09	0.011	0.237	2.551
Total	34,860	0.020	0.030	3.91E-09	0.008	0.346	3.253

Panel (c) Japanese firms, balanced panel for firms with 50 or more employees and 30 million yen or more of paid-in capital

Year	Obs.	Mean	SD	Min.	Median	Max.	Skewness
1995	3,068	0.018	0.020	3.92E-05	0.010	0.108	1.754
1996	3,002	0.018	0.021	1.80E-05	0.010	0.113	1.784
1997	3,000	0.019	0.021	1.70E-05	0.010	0.114	1.728
1998	2,976	0.020	0.023	1.61E-05	0.011	0.125	1.695
1999	3,002	0.020	0.023	1.60E-05	0.012	0.120	1.616
2000	2,939	0.020	0.022	1.60E-05	0.011	0.122	1.744
2001	2,943	0.021	0.025	2.56E-05	0.012	0.142	1.853
2002	2,931	0.020	0.024	1.75E-05	0.011	0.135	1.844
2003	2,901	0.020	0.024	4.11E-05	0.011	0.138	1.851
2004	2,945	0.020	0.023	2.20E-05	0.011	0.132	1.833
2005	2,939	0.019	0.023	3.27E-05	0.011	0.135	1.914
2006	2,882	0.020	0.024	3.92E-05	0.010	0.147	2.042
2007	2,823	0.020	0.024	2.77E-05	0.010	0.151	2.110
2008	2,808	0.022	0.028	2.04E-05	0.011	0.176	2.273
Total	41,159	0.020	0.023	1.60E-05	0.011	0.176	1.920

Panel (d) Korean firms, balanced panel for firms with 50 or more employees and 300 million won or more of paid-in capital

Year	Obs.	Mean	SD	Min.	Median	Max.	Skewness
1995	957	0.008	0.013	1.00E-08	0.003	0.089	2.931
1996	996	0.009	0.013	3.91E-09	0.004	0.101	2.997
1997	977	0.010	0.015	3.14E-08	0.005	0.117	2.906
1998	997	0.013	0.019	1.02E-08	0.005	0.193	3.396
1999	969	0.010	0.015	1.63E-06	0.004	0.145	3.292
2000	993	0.012	0.018	3.60E-08	0.005	0.181	3.296
2001	1,015	0.014	0.022	1.18E-07	0.006	0.288	4.073
2002	1,006	0.014	0.021	1.30E-08	0.006	0.164	3.173
2003	1,007	0.014	0.019	6.73E-07	0.007	0.124	2.390
2004	989	0.014	0.020	3.01E-08	0.007	0.181	3.096
2005	956	0.015	0.022	1.24E-07	0.008	0.240	3.634
2006	974	0.015	0.019	4.96E-09	0.007	0.173	2.575
2007	996	0.016	0.021	1.01E-07	0.008	0.267	3.311
2008	947	0.016	0.021	9.42E-09	0.007	0.153	2.668
Total	13,779	0.013	0.019	3.91E-09	0.006	0.288	3.341

Note: Observations with a higher R&D intensity than the 99th percentile value for each country year or with an R&D intensity exceeding one are excluded.

Appendix Table 3. Characteristics of Japanese and Korean firms

	Japanese manufacturing firms											
	All firms						R&D performing firms					
	Obs.	Mean	SD	Min.	Median	Max.	Obs.	Mean	SD	Min.	Median	Max.
No. of employees	180,998	401	1,684	50	141	80,840	82,144	656	2,421	50	209	80,840
Sales (mil. yen)	180,998	20,890	146,296	31	3,701	12,100,000	82,144	37,453	210,625	136	6,214	12,100,000
Sales growth (%)	151,155	-0.008	13.946	-67.413	0.211	63.473	69,907	0.304	13.515	-67.404	0.620	63.473
I/K (%)	149,518	13	23	-53	7	494	69,541	14	22	-51	8	441
I/S (%)	149,518	3	5	-18	2	39	69,541	3	5	-17	2	38
K/S (%)	180,349	34.7	27.4	0.1	28.6	503.0	82,044	34.3	25.2	0.1	29.0	482.1
C/K (%)	178,771	34	95	-325	19	3,121	81,699	34	80	-321	22	3,121

	Korean manufacturing firms											
	All firms						R&D performing firms					
	Obs.	Mean	SD	Min.	Median	Max.	Obs.	Mean	SD	Min.	Median	Max.
No. of employees	50,587	316	1,685	50	118	85,813	32,247	399	2,081	50	135	85,813
Sales (mil. yen)	56,621	12,357	108,861	0	2,357	8,006,750	34,175	16,076	131,565	2	2,877	8,006,750
Sales growth (%)	46,458	12.047	26.711	-90.628	9.567	220.112	29,317	11.924	26.415	-90.628	9.641	216.712
I/K (%)	46,563	37	78	-57	15	1,826	29,361	37	74	-57	16	1,645
I/S (%)	46,456	9	16	-27	4	337	29,313	10	16	-27	4	337
K/S (%)	56,602	41.5	49.3	0.1	30.5	1,702.8	34,172	40.1	42.4	0.1	30.8	1,702.8
C/K (%)	56,783	56	151	-1,416	30	6,881	34,197	52	130	-1,208	31	5,158

Notes: Outliers are excluded. First, firms whose R&D intensity exceeds one are excluded. Then, for the ratios I/K, I/S, K/S, and C/K we drop firms for which the ratio is smaller than the first percentile or larger than the 99th percentile.

The sales amounts in the table are nominal values and the sales growth rates are calculated based on the nominal sales amounts. The sales amounts of Korean firms are converted into Japanese yen using the nominal exchange rate.

I: investment, K: fixed assets, S: sales, C: cash flow.