

“A Comparative Analysis of Productivity Growth and Productivity Dispersion:
Microeconomic Evidence Based on Listed Firms from Japan, Korea, and China”

Keiko Ito, Moosup Jung, Young Gak Kim, Tangjun Yuan

April 2008

College of Economics, Nihon University

**A Comparative Analysis of Productivity Growth and Productivity Dispersion:
Microeconomic Evidence Based on Listed Firms from Japan, Korea, and China**

Keiko Ito (Senshu University)*

Moosup Jung (Seoul National University)

Young Gak Kim (Hitotsubashi University)

Tangjun Yuan (Hitotsubashi University)

ABSTRACT

Utilizing the firm-level dataset, this study aims to explore differences in firm-level productivity and growth between Japan, Korea, and China, while at the same time illuminating the mechanism that has driven the narrowing in the productivity gap that can be observed. We pursue two strategies. First, we compare the firm-level TFP distribution of major industries in these three countries over time to examine catch-up patterns within and across industries. Second, in order to examine patterns of technology diffusion across these three countries, we conduct a regression analysis on TFP convergence to the national frontier and to the global frontier.

Our main results can be summarized as follows. First, although Japanese firms enjoy the highest average TFP level in many industries, their TFP growth rate has been relatively low during the past two decades. Korean firms have achieved considerable TFP growth in certain industries. The average TFP level of Chinese firms is still much lower than that of Japanese and Korean firms in many industries. Second, within-industry dispersion of TFP levels is very small for Japanese firms. While the within-industry ranking of TFP levels hardly changes in the case of Japan, fluctuations in the ranking are relatively frequent in the case of Korea. Third, in Korea, the TFP levels of low-performing firms are approaching those of the national frontier firms at a more rapid pace than in Japan.

JEL classification: D24, L25, O53, O57

Keywords: total factor productivity, micro data, TFP growth, productivity dispersion, listed firms, Japan, Korea, China

*Corresponding author: Keiko Ito, Faculty of Economics, Senshu University, 2-1-1, Higashi-Mita, Tama-ku, Kawasaki 214-8580 JAPAN. Tel.: +81-44-900-7818, fax.: +81-44-911-0467, e-mail: keiko-i@isc.senshu-u.ac.jp.

A previous version of this paper was presented at the 15th Seoul Journal of Economics International Symposium, *Productivity and Performance of the Firms in Korea, Japan, and China* (sic), October 23, 2007, Seoul National University, Seoul, Korea. The authors are grateful to Wooseok Ok, Yoshitsugu Kitazawa, and other conference participants for helpful comments.

1. Introduction

East Asia's dramatic economic growth post World War II has been widely characterized as nothing short of a miracle, the determinants and effects of which have been examined and analyzed by academics, business practitioners, and governments alike. The pattern of economic development in the region has been frequently described in terms of the "Flying Geese" paradigm, with Japan the first to achieve rapid economic growth, followed by Korea and the other newly-industrializing economies (NIEs), the Association of South East Asian Nation (ASEAN) countries, and finally China (Kojima 2003). However, although Japan continues to be the most advanced country in the region in terms of total factor productivity (TFP) in a large number of manufacturing industries,¹ in certain industries, other Asian countries are already more productive than Japan. Moreover, in recent years, Japan's economic growth rate has been outpaced by its East Asian neighbors, suggesting that the productivity gap between Japan and the rest of East Asia is shrinking (Motohashi 2005).

Many previous studies have investigated the convergence or divergence of macro- or industry-level productivity performance in an attempt to discover the sources of economic growth. At the macro level, previous studies underline the role of technological progress, human capital, institutions, and market structure in explaining the economic performance of different countries and industries (Barro and Sala-i-Martin 2004, Hall and Jones 1999, etc.). More recently, utilizing micro data, the divergence or convergence of productivity among firms has been intensively scrutinized, providing us with insights into the mechanisms underlying productivity convergence or divergence across countries. The large body of literature on micro-level productivity has shown that firms' managerial ability, use of technology, human capital, competitive pressure, and technology diffusion or spillovers are important determinants of productivity levels and productivity growth.² On the other hand, empirical studies focusing on the connection between aggregate and micro productivity growth have examined the contribution of resource reallocation across firms to aggregate productivity growth, based on the idea that aggregate productivity grows faster if more inputs and output are allocated to high-productivity firms and less to low-productivity firms.

However, the number of micro-level productivity analyses from an international comparative perspective is very limited.³ Most recent micro-level studies compare productivity levels or

¹ According to Motohashi (2005), China's, Korea's, and Taiwan's relative TFP levels were lower than Japan's in most industries in 1995. However, in non-electrical machinery, the TFP gap between Japan and Korea, at approximately 4%, was very small, while Taiwan's TFP level in fact was higher than Japan's by 14%. On the other hand, in the fabricated metal sector, the Korean TFP level was 28% higher and the Taiwanese TFP level was 4% lower than Japan's.

² For a comprehensive literature survey on this issue, see Bartelsman and Doms (2000).

³ In contrast, there have been extensive international productivity comparisons at the industry or macro

growth within a country or examine whether non-frontier firms within the country are catching up with national frontier firms. Unfortunately, such studies on individual countries remain silent on whether productivity across countries is converging, since they cannot identify the global technology frontier that is the hypothesized source of knowledge spillovers. However, a small number of pioneering works on the international comparison of productivity and firm dynamics based on micro data do exist, such as Bartelsman, Scarpetta and Schivardi (2003) and Bartelsman, Haltiwanger and Scarpetta (2004, 2005), which attempt to explore the country-specific factors that affect aggregate patterns of productivity growth. Although the coverage of the datasets of these studies differs across countries, they do manage to compile comprehensive firm-level data covering almost all firms in manufacturing and other industries. Unfortunately, however, Japan and China are not analyzed in these studies. Although Korea is included in the study by Bartelsman, Haltiwanger and Scarpetta (2004, 2005), no TFP analysis for Korea is conducted.

In 2006, the Japan Center for Economic Research launched a research project on the “Comparison of the Productivity of Japanese, Chinese, Korean and European Firms,” which aims at developing a methodology for TFP comparison in an international context and also at investigating patterns of productivity growth and convergence across countries at the micro-level. As members of this project, we compiled firm-level data to examine whether and how firm-level TFP growth characteristics differ in Japan, Korea, and China. Although our firm-level dataset is limited to listed firms, as far as we know, this is the first comprehensive comparative study on firm-level TFP in these countries.

These three East Asian countries are still at different stages of economic development, although they achieved industrialization one after another as explained by the “Flying Geese” hypothesis mentioned above. Utilizing the dataset we constructed, this study specifically aims to explore differences in productivity and growth between Japan, Korea, and China, while at the same time illuminating the mechanism that has driven the narrowing in the productivity gap that can be observed and will be described in detail below. In this study, we pursue two strategies. First, we compare the firm-level TFP distribution of major industries in these three countries over time to examine catch-up patterns within and across industries. Second, in order to examine patterns of technology diffusion across these three East Asian countries, we conduct a regression analysis on TFP convergence to the national frontier and to the global frontier.

However, we should note that our analysis is limited to listed firms in these countries and we cannot say that the performance of listed firms represents industry- or macro-level economic

level, conducted by the EU KLEMS project (see <http://www.euklems.net>) and at the Groningen Growth and Development Centre at the Economics Department of the University of Groningen (see <http://www.ggdcc.net>). A comparative study of East Asian countries has been conducted by the ICPA (International Comparison of Productivity Among Asian Countries) project at RIETI (Research Institute of Economy, Trade and Industry) in Japan (see <http://www.rieti.go.jp/jp/database/data/icpa-description.pdf>).

performance. Particularly in China, most foreign-owned firms are not listed; yet, foreign-owned firms are generally considered to be a major driving force of economic development and technology upgrading in the country. But even with these shortcomings, this comparative study is meaningful for the following reasons: (1) it is the first study which compares TFP levels among these countries based on firm-level data; (2) as listed firms tend to be large and more representative of each country, an international comparison focusing specifically on listed firms may in fact be more meaningful; put differently, given the differences in economic development, it is difficult to compare very small firms in a developing country with firms in a developed country; and (3) using firm-level data for listed firms allows us, at least in the case of Japan and Korea, for which sufficient data are available, to examine TFP performance over a long period of time.

Our main results can be summarized as follows. First, although Japanese firms enjoy the highest average TFP level in many industries, their TFP growth rate has been relatively low during the past two decades. On the other hand, Korean firms have achieved considerable TFP growth in certain industries, and in the electrical and general machinery industries, their TFP growth has outpaced that of Japanese firms in recent years. The average TFP level of Chinese firms is still much lower than that of Japanese and Korean firms in many industries. Second, within-industry dispersion of TFP levels is very small for Japanese firms when compared with Korean and Chinese firms. Comparing time-series data for Japan and Korea, we find that that in both countries the within-industry dispersion of TFP levels has been expanding in many industries. However, while the within-industry ranking of TFP levels hardly changes in the case of Japan, fluctuations in the ranking are relatively frequent in the case of Korea. In Japan, higher-performing firms tend to remain at a higher ranking and lower-performing firms tend to remain at a lower ranking for a long period. Third, in Korea, the TFP levels of low-performing firms are approaching those of the national frontier firms at a more rapid pace than in Japan.

The remainder of this paper is organized as follows. Section 2 describes the characteristics of our firm-level datasets and compares firm- and industry-level TFP for Japan, Korea, and China. In Section 3, we investigate the TFP dispersion within an industry, while in Section 4, we conduct an econometric analysis to explore the TFP convergence mechanism in these three countries. Section 5 concludes and makes suggestions for the future direction of international comparative studies on productivity growth and convergence.

2. Firm- and Industry-Level TFP for Japan, Korea, and China

2.1 Data

In this section, we first describe the major characteristics of listed firms in Japan, Korea, and China based on our firm-level dataset. We then examine the firm- and industry-level TFP growth for these three countries, focusing on several major industries.⁴

We construct the firm-level TFP measure using annual financial data for the period 1985-2004 for Japan and Korea and for the period 1999-2004 for China.⁵ Table 1 summarizes the number of firms in each industry and country.⁶ We should note the following drawbacks of our dataset. First, because there is no information on the year of listing and delisting for Korea and China, we identified firms which were delisted during our sample period using various data sources. Although we were able to identify the year of delisting for all Korean firms, we were only partially successful in the case of Chinese firms. Second, the Korean database includes historical financial data for firms which were listed as of 1990 and therefore does not include data for firms which were delisted before 1990. This may be a possible reason why the number of Korean firms delisted during the period 1985-1995 is zero. Third, for Korean firms listed after 1990, the database includes the financial data before the listing if the firm was “sufficiently large.”⁷ Therefore, for Korean firms, we should interpret the “entry” to the stock market as the time when the firm size became “sufficiently large” (see footnote 7). In the case of Chinese firms, approximately 20 out of the 87 firms which exited the stock market are confirmed to have been delisted. However, there are others which were dropped from our dataset due to missing variables. Therefore, we should note that in the case of China, the number of exited firms in our dataset does not necessarily correspond to the number of firms that actually did delist from the stock market.

Looking at Table 1, it can be seen that in most industries, the number of Japanese firms in our dataset is larger than that of Korean or Chinese firms. Moreover, in the case of Japan, the number of exited firms increased in the period from 1995-2004 compared to 1985-1995. For some industries, the number of observations, particularly observations of Korean and Chinese firms, is extremely small. Therefore, in our productivity analysis we focus on the following 12 industries

⁴ For an explanation of our methodology of constructing a TFP measure that is comparable across countries, see the Appendix. Refer also to Fukao et al. (2007).

⁵ We were not able to calculate TFP for China before 1999 due to data constraints. For the TFP calculation, we exclude observations whose output or input data are negative or missing. Moreover, we exclude outliers whose calculated TFP level is larger (smaller) than the country-industry-year average plus/minus three standard deviations. However, we do not exclude such outliers in the case of China because of the small sample size for China.

⁶ Outliers are excluded from the numbers presented in Table 1.

⁷ However, the threshold size of “sufficiently large” firms differs from year to year. Before 1988, the database includes financial data for firms whose total assets exceeded 3 billion won or whose capital exceeded 0.5 billion won. The database includes financial data for firms whose total assets exceeded 3 billion won for the years 1988-1990, 4 billion won for the years 1990-1993, 6 billion won for the years 1993-1998, and 7 billion won for years after 1998. However, several firms which do not meet these criteria are included in the database.

with a relatively large number of observations: construction; food and kindred products; textile mill products; apparel; paper and allied products; chemicals; stone, clay and glass products; primary metal products; non-electrical machinery; electrical machinery; motor vehicles; and transportation.

Table 1. Number of listed firms and firm turnover

(a) Japan	1985	1985-1995		1995	1995-2004		2004
	No. of Firms	Entry	Exit	No. of Firms	Entry	Exit	No. of Firms
1 Agriculture	2	2	0	4	0	1	3
2 Coal mining	3	0	0	3	0	0	3
3 Metal and nonmetallic mining	2	0	0	2	0	0	2
4 Oil and gas extraction	3	0	0	3	3	1	5
5 Construction	143	83	4	222	38	45	215
6 Food and kindred products	98	46	1	143	28	15	156
7 Textile mill products	50	4	2	52	1	8	45
8 Apparel	22	10	0	32	2	6	28
9 Lumber and wood	6	5	0	11	0	2	9
10 Furniture and fixtures	7	5	0	12	2	2	12
11 Paper and allied products	32	7	3	36	6	12	30
12 Printing, publishing and allied products	10	17	0	27	17	3	41
13 Chemicals	156	58	4	210	31	22	219
14 Petroleum and coal products	10	0	0	10	1	2	9
15 Leather	1	2	0	3	0	0	3
16 Stone, clay and glass products	64	27	8	83	8	13	78
17 Primary metals	98	17	4	111	6	24	93
18 Fabricated metals	56	44	0	100	10	14	96
19 Non-electrical machinery	178	70	2	246	28	41	233
20 Electrical machinery	156	88	2	242	79	38	283
21 Motor vehicles	83	28	0	111	16	14	113
22 Transportation equipment and ordnance	28	4	0	32	2	8	26
23 Instruments	32	19	0	51	13	8	56
24 Rubber and misc. plastics	39	28	0	67	10	9	68
25 Misc. manufacturing	16	28	0	44	18	5	57
26 Transportation	104	38	3	139	13	17	135
27 Communication	2	4	0	6	16	1	21
28 Electrical utilities	9	1	0	10	2	0	12
29 Gas utilities	12	1	0	13	3	1	15
30 Trade	212	337	13	536	222	89	669
31 Finance, insurance and real estate	23	30	2	51	61	12	100
32 Other private services	70	192	2	260	421	28	653
33 Public service	1	0	0	1	0	0	1

Table 1. Number of Listed Firms and Firm Turnover (continued)

	1985		1985-1995		1995		1995-2004		2004
	No. of Firms	Entry	Exit	No. of Firms	Entry	Exit	No. of Firms		
1 Agriculture	5	1	0	6	0	0	6		
2 Coal mining	1	0	0	1	0	0	1		
3 Metal and nonmetallic mining	0	0	0	0	0	0	0		
4 Oil and gas extraction	0	0	0	0	0	0	0		
5 Construction	44	14	0	58	4	3	59		
6 Food and kindred products	48	10	0	58	8	1	65		
7 Textile mill products	19	8	0	27	2	1	28		
8 Apparel	18	11	0	29	7	3	33		
9 Lumber and wood	3	1	0	4	1	0	5		
10 Furniture and fixtures	4	0	0	4	1	0	5		
11 Paper and allied products	25	8	0	33	0	0	33		
12 Printing, publishing and allied products	1	4	0	5	12	0	17		
13 Chemicals	101	38	0	139	32	2	169		
14 Petroleum and coal products	4	1	0	5	0	0	5		
15 Leather	5	5	0	10	2	1	11		
16 Stone, clay and glass products	28	2	0	30	5	0	35		
17 Primary metals	42	26	0	68	10	1	77		
18 Fabricated metals	15	20	0	35	8	3	40		
19 Non-electrical machinery	28	45	0	73	57	7	123		
20 Electrical machinery	71	133	0	204	169	21	352		
21 Motor vehicles	32	25	0	57	13	1	69		
22 Transportation equipment and ordnance	7	1	0	8	2	0	10		
23 Instruments	8	15	0	23	14	0	37		
24 Rubber and misc. plastics	14	12	0	26	11	1	36		
25 Misc. manufacturing	5	4	0	9	3	1	11		
26 Transportation	18	2	0	20	3	0	23		
27 Communication	3	3	0	6	4	0	10		
28 Electrical utilities	1	0	0	1	0	0	1		
29 Gas utilities	10	1	0	11	0	0	11		
30 Trade	44	28	0	72	29	2	99		
31 Finance, insurance and real estate	0	0	0	0	0	0	0		
32 Other private services	15	59	0	74	151	7	218		
33 Public service	0	0	0	0	0	0	0		

Table 1. Number of Listed Firms and Firm Turnover (continued)

(c) China	1999	1999-2004		2004
	No. of Firms	Entry	Exit	No. of Firms
1 Agriculture	13	14	3	24
2 Coal mining	4	8	1	11
3 Metal and nonmetallic mining	3	2	0	5
4 Oil and gas extraction	2	2	0	4
5 Construction	9	11	3	17
6 Food and kindred products	29	25	1	53
7 Textile mill products	17	13	2	28
8 Apparel	6	6	1	11
9 Lumber and wood	0	0	0	0
10 Furniture and fixtures	1	1	0	2
11 Paper and allied products	10	7	0	17
12 Printing, publishing and allied products	2	2	0	4
13 Chemicals	106	81	7	180
14 Petroleum and coal products	9	5	1	13
15 Leather	1	1	0	2
16 Stone, clay and glass products	26	23	3	46
17 Primary metals	25	25	1	49
18 Fabricated metals	8	4	1	11
19 Non-electrical machinery	46	28	4	70
20 Electrical machinery	84	51	10	125
21 Motor vehicles	17	17	2	32
22 Transportation equipment and ordnance	13	6	0	19
23 Instruments	7	4	0	11
24 Rubber and misc. plastics	9	11	0	20
25 Misc. manufacturing	8	7	2	13
26 Transportation	22	26	4	44
27 Communication	21	19	4	36
28 Electrical utilities	21	19	2	38
29 Gas utilities	4	2	1	5
30 Trade	60	21	9	72
31 Finance, insurance and real estate	46	17	21	42
32 Other private services	30	12	4	38
33 Public service	0	0	0	0

Table 2 compares the average size of firms by industry and country. We use the number of employees per firm and the total assets per firm as measures of firm size. In Table 2, the columns labeled “cross country average” show the average size of firms for all three countries. The three following columns then show the ratio of the average size of firms in each country to the three-country average. Therefore, the average firm size in a particular country is larger than the three-country average if the ratio is greater than 1. As we can see from Table 2, Chinese firms are the largest in terms of employment, while Japanese firms are the largest in terms of assets.

Table 2. Within-industry average firm size for 2004: as a share of cross-country sectoral average (Number of employees per firm)

	Number of employees per firm				Total assets per firm			
	Cross country average	Japan	Korea	China	Cross country average (mil. US\$)	Japan	Korea	China
1 Agriculture	3,024	0.13	0.18	1.31	207	1.19	0.66	1.06
2 Coal mining	8,771	0.04	0.04	1.35	375	1.49	0.54	0.91
3 Metal and nonmetallic mining	2,128	0.05	n.a.	1.38	173	1.30	n.a.	0.88
4 Oil and gas extraction	44,641	0.01	n.a.	2.24	7,223	0.22	n.a.	1.96
5 Construction	1,217	1.03	0.51	2.37	974	1.15	0.63	0.41
6 Food and kindred products	1,505	0.62	0.68	2.50	688	1.38	0.57	0.40
7 Textile mill products	1,530	0.57	0.22	2.47	490	1.83	0.24	0.42
8 Apparel	1,520	0.33	0.24	4.97	210	1.34	0.47	1.73
9 Lumber and wood	544	1.11	0.80	n.a.	320	1.17	0.69	n.a.
10 Furniture and fixtures	1,154	0.95	0.46	2.66	406	1.43	0.34	0.27
11 Paper and allied products	1,116	0.81	0.25	2.79	671	2.09	0.30	0.43
12 Printing, publishing and allied products	846	1.24	0.27	1.61	638	1.48	0.08	0.12
13 Chemicals	1,422	0.74	0.38	1.89	642	1.93	0.48	0.36
14 Petroleum and coal products	3,767	0.18	0.40	1.80	2,196	1.47	1.81	0.36
15 Leather	666	0.33	0.39	5.38	149	2.06	0.55	1.91
16 Stone, clay and glass products	1,400	0.57	0.38	2.20	536	1.43	0.74	0.47
17 Primary metals	2,372	0.50	0.28	3.09	1,118	1.53	0.56	0.71
18 Fabricated metals	696	0.88	0.44	4.05	345	1.22	0.40	1.22
19 Non-electrical machinery	1,110	1.08	0.20	2.14	606	1.64	0.14	0.37
20 Electrical machinery	1,595	1.13	0.38	2.44	769	2.03	0.36	0.48
21 Motor vehicles	3,192	1.15	0.57	1.41	1,795	1.58	0.39	0.23
22 Transportation equipment and ordnance	2,419	0.31	2.25	1.29	862	0.62	3.45	0.23
23 Instruments	729	1.20	0.33	2.20	389	1.66	0.21	0.31
24 Rubber and misc. plastics	1,106	0.90	0.56	2.14	565	1.44	0.41	0.55
25 Misc. manufacturing	629	0.88	0.36	2.07	444	1.28	0.18	0.49
26 Transportation	2,862	1.11	0.67	0.85	2,065	1.26	0.67	0.37
27 Communication	2,304	0.66	2.05	0.91	3,512	2.24	1.23	0.18
28 Electrical utilities	4,786	2.18	3.78	0.56	9,788	3.48	5.82	0.09
29 Gas utilities	1,327	1.31	0.42	1.33	1,707	1.46	0.76	0.15
30 Trade	834	0.88	0.61	2.67	768	1.14	0.54	0.34
31 Finance, insurance and real estate	688	0.66	n.a.	1.81	1,069	1.23	n.a.	0.38
32 Other private services	714	0.93	0.33	6.11	248	1.22	0.34	0.94
33 Public service	85	1.00	n.a.	n.a.	116	1.00	n.a.	n.a.

n.a. = not available.

Notes: Total assets are presented in US dollar terms. Values of total assets in local currency are converted to values in US dollars using market exchange rates at year-end.

Figures exceeding one are shaded.

Table 3 shows the number of firms by stock market. In Japan, stock markets are divided into a first section for relatively large firms, a second section for smaller firms, and markets for start-ups such as the JASDAQ market.⁸ Moreover, following the amendment of stock trading laws, new stock exchange markets for start-up firms such as Hercules and Mothers were established at the end of the 1990s. Similarly in Korea, there are two stock markets: the KSE for relatively large firms and the KOSDAQ, founded in 1996, for start-up firms.⁹ In China, there are the Shanghai Stock Exchange and the Shenzhen Stock Exchange. As shown in Table 3, the number of listed firms in Japan, and especially that of firms listed in the Second Section and on JASDAQ, has increased remarkably. In Korea, the number of firms listed on KOSDAQ exceeds that of firms listed on the KSE, probably reflecting the fact that the number of start-up firms has increased very rapidly in recent years. In China, the number of firms listed on the Shanghai Stock

⁸ In 2001, the over-the-counter market was renamed the JASDAQ market. In Table 3, "JASDAQ" refers to the over-the-counter market in 1985 and 1995.

⁹ Although the KOSDAQ was founded in 1996, there exist firms listed on the KOSDAQ before 1996. This is because our database contains historical financial data for relatively large firms as mentioned above.

Exchange is larger than that of firms listed on the Shenzhen Stock Exchange.

Table 3. Number of firms by stock market

	1985	1995	2004*
Japan: Total	1,728	2,873	3,521
1st Section	1,029	1,322	1,558
2nd Section	373	634	805
JASDAQ	0	465	908
Other	0	0	230
Korea: Total	619	1,096	1,563
KSE	485	545	613
KOSDAQ	134	551	950
China: Total	n.a.	n.a.	1,042
Shanghai	n.a.	n.a.	641
Shenzhen	n.a.	n.a.	401

* Data are for 2005 in the case of Korea.

n.a. = not available.

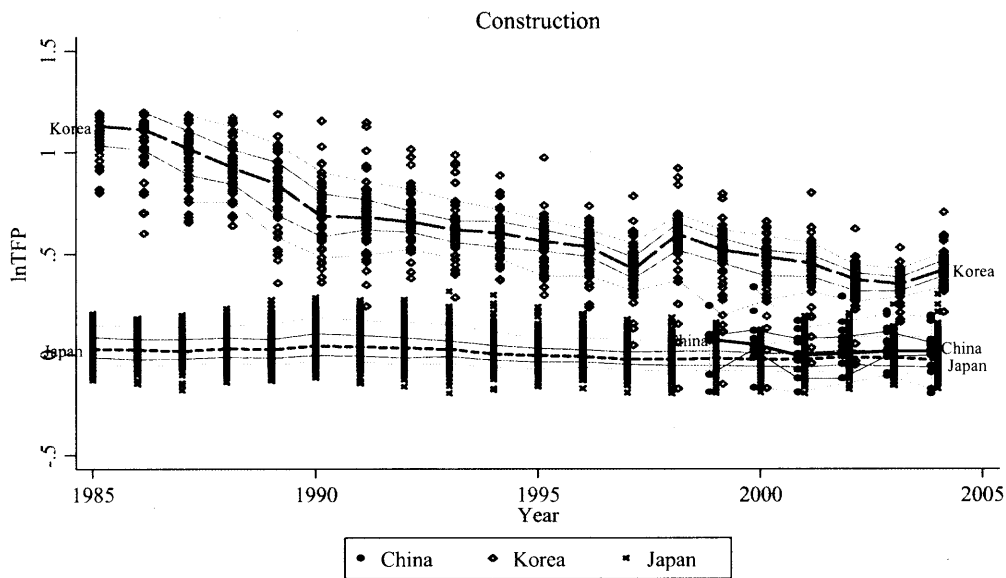
2.2 TFP trends in major industries in Japan, Korea, and China

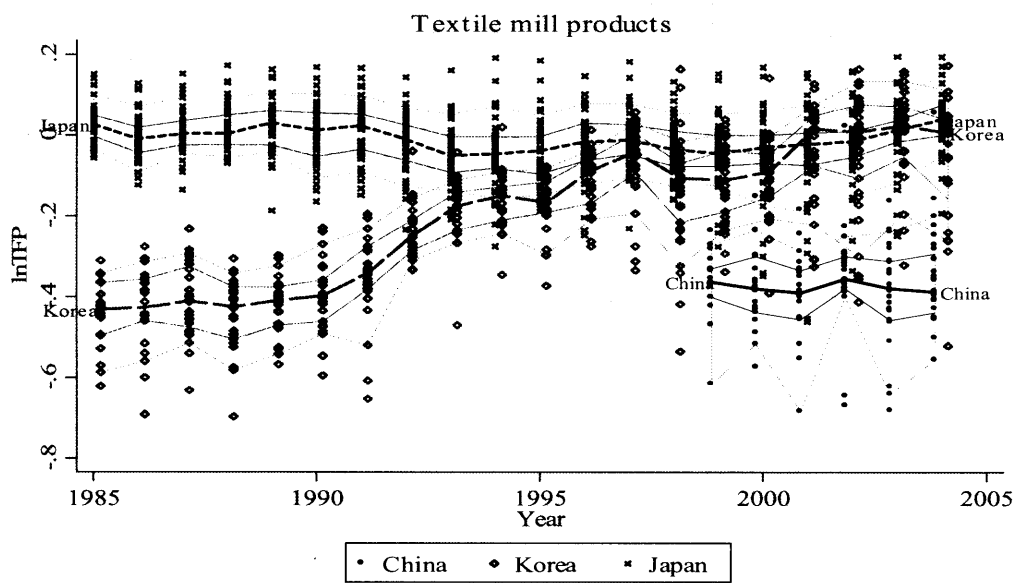
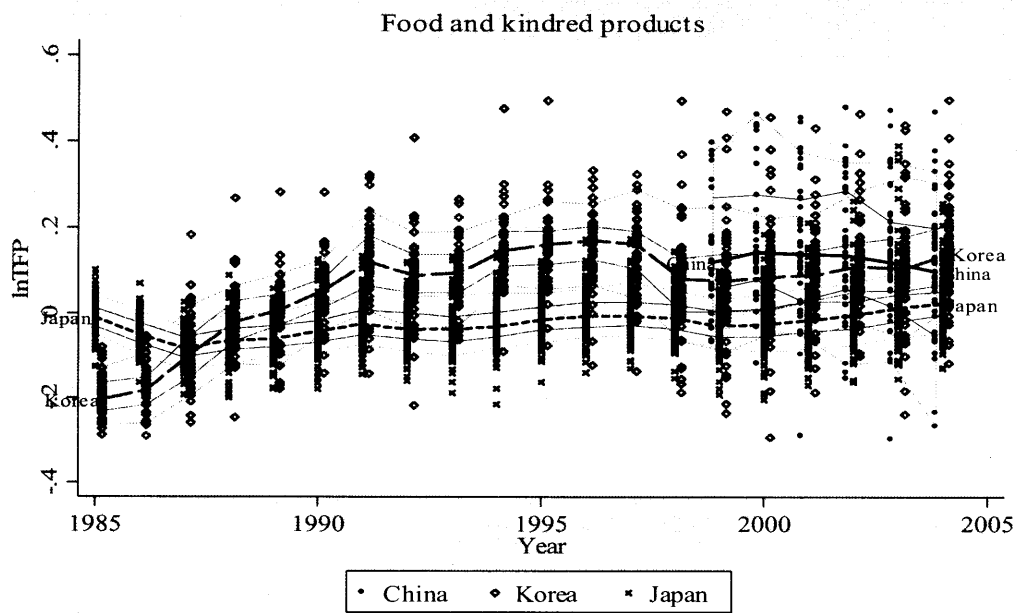
Next, let us look at the distribution of firm-level TFP by industry and the trend of median TFP levels for each industry (Figure 1). For all 12 industries in Figure 1, Japanese firms show the smallest dispersion of TFP within each industry when compared with Korean and Chinese firms. Moreover, for Japanese firms, the median TFP level has been almost flat in all industries except the electrical machinery industry. On the other hand, in the case of Korea, the median TFP level as well as the overall TFP distribution have been shifting upwards in industries such as textile mill products, apparel, non-electrical machinery, electrical machinery, motor vehicles, and transportation. As a result, the Korean median TFP level has caught up with or surpassed the Japanese median TFP level in the textile mill products and electrical machinery industries. In chemicals and motor vehicles, the Korean median TFP level had caught up with the Japanese median TFP level but more recently has fallen behind again. In the stone, clay and glass products and the non-electrical machinery industries, the Korean median TFP level has been higher than that of Japan since the mid-1990s. In the transportation industry, Japanese TFP has been stagnating, whereas Korean TFP has been increasing since the mid-1990s, so that in recent years it has been much higher than Japanese TFP.

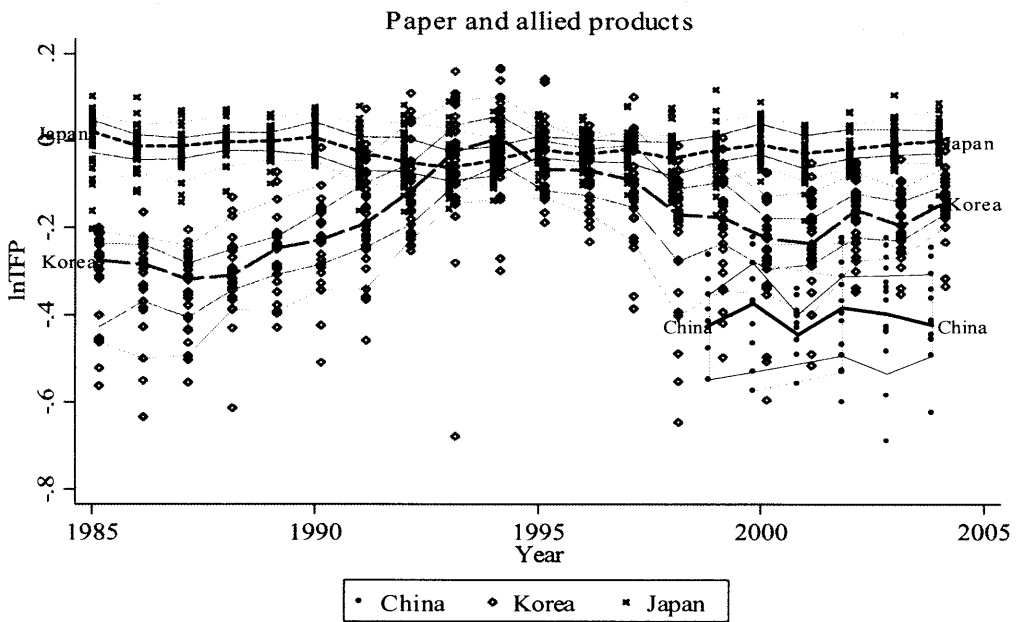
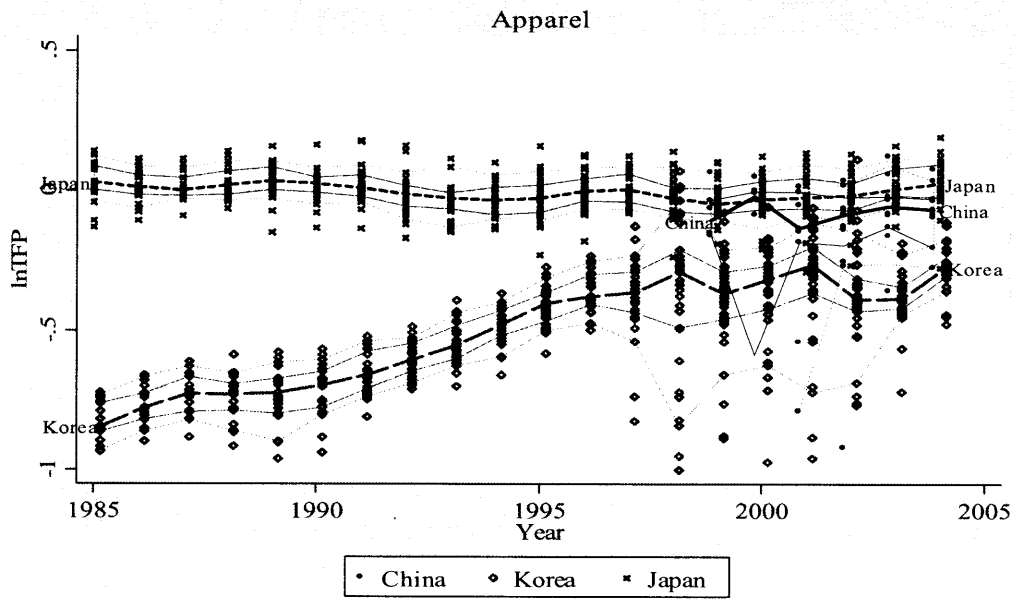
The median TFP of Chinese firms is much lower than that of Japanese and Korean firms in most industries, with the exception of apparel and transportation. Although it is believed that the technological capabilities of the machinery industries in China have been improving and the production of high-tech machinery parts and components has been increasing, the overall TFP

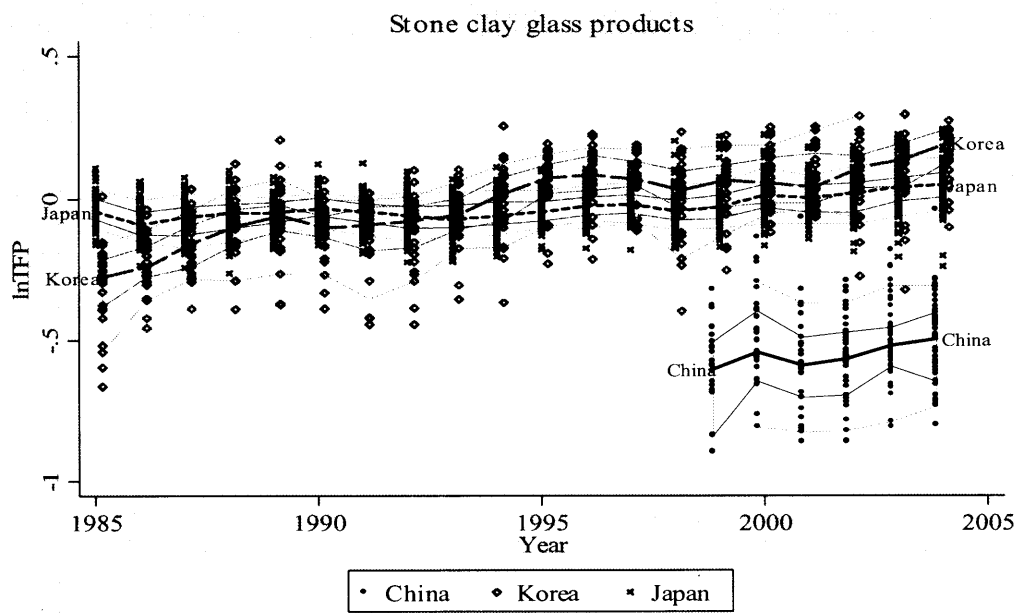
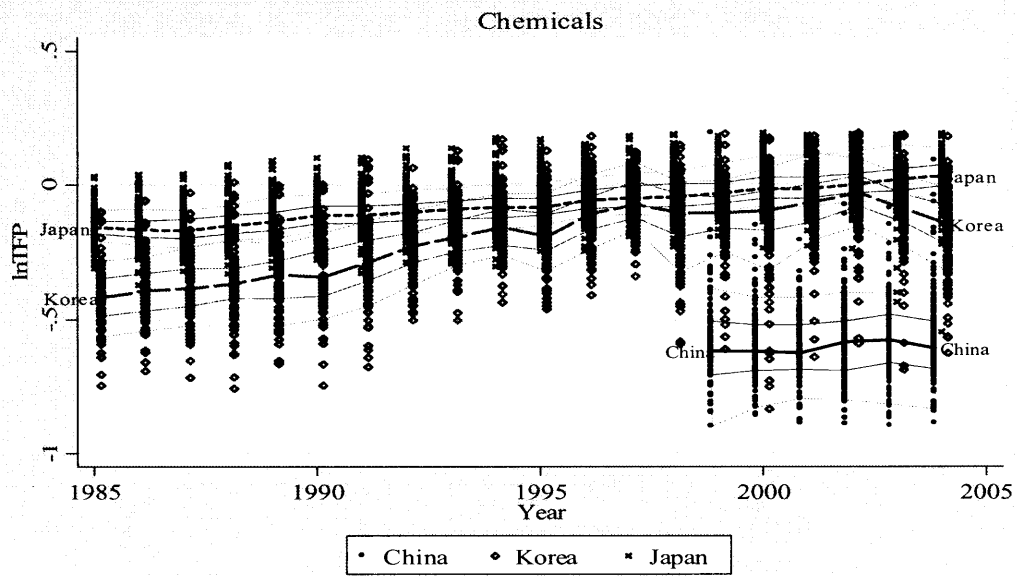
level of Chinese listed firms in the sector is still much lower than that of Japanese and Korean firms. A possible explanation for this is that technological progress has been largely led by foreign-owned firms, most of which are not listed on Chinese stock exchanges and therefore not included in our dataset. Chinese stock markets were under full control by the government until 2000, and only firms assigned by the government had been able to get listed. Therefore, many Chinese listed firms are former state-owned enterprises and not always high performing. In the motor vehicles industry, for example, the overall TFP level of Chinese firms is significantly lower than that of Japanese and Korean firms, although our dataset includes major joint-ventures between foreign automobile manufacturers and Chinese local firms.

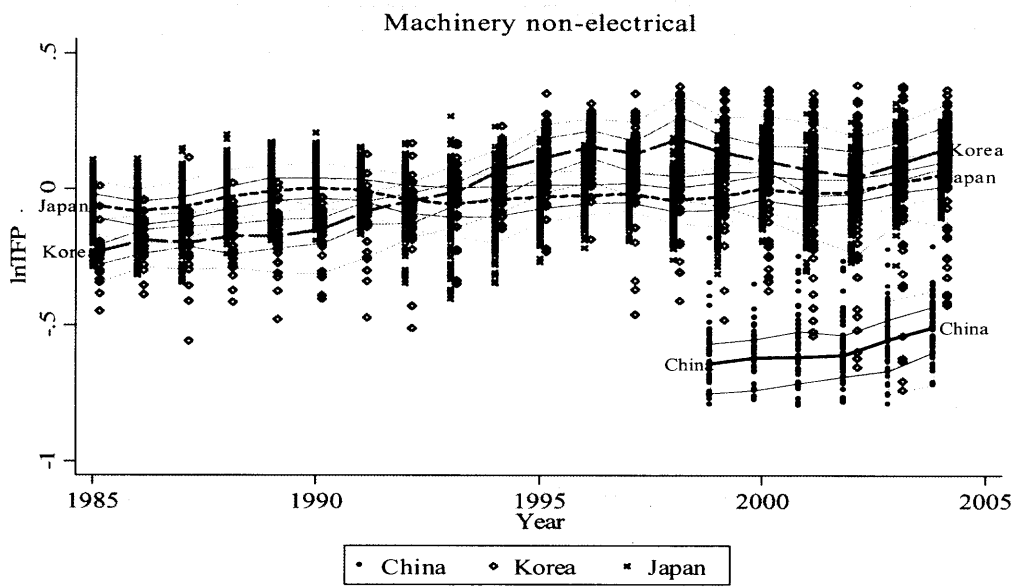
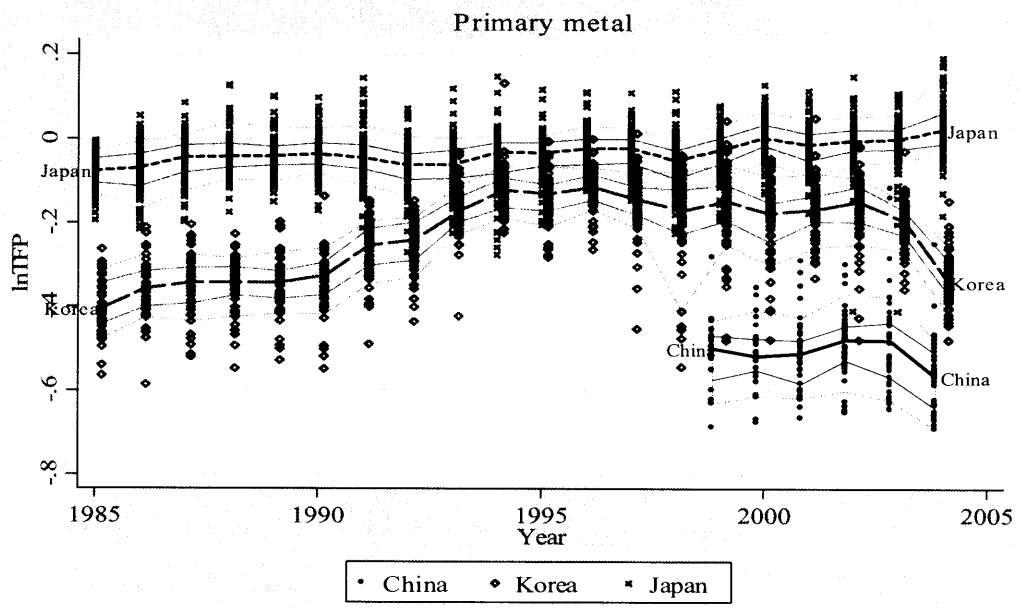
Figure 1. Distribution of firm TFP and trend of the median TFP level

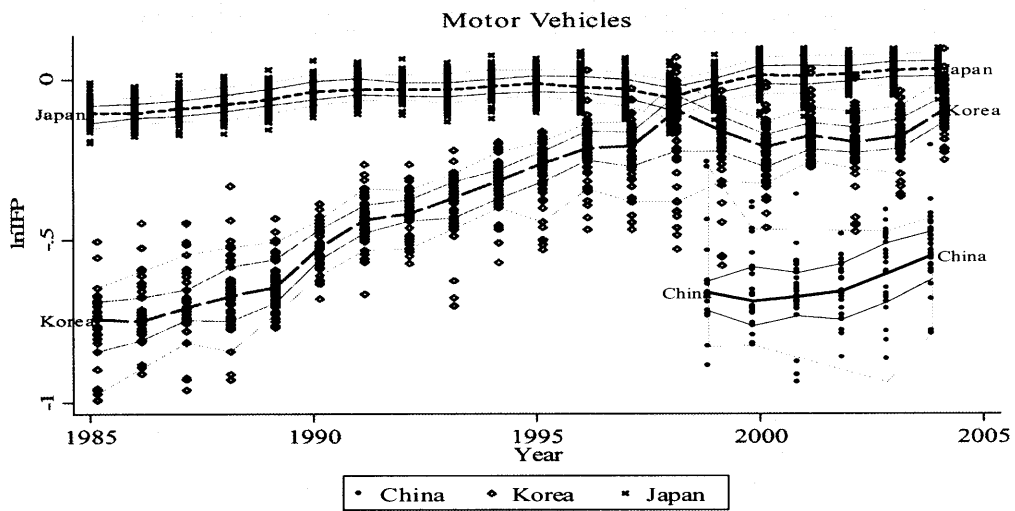
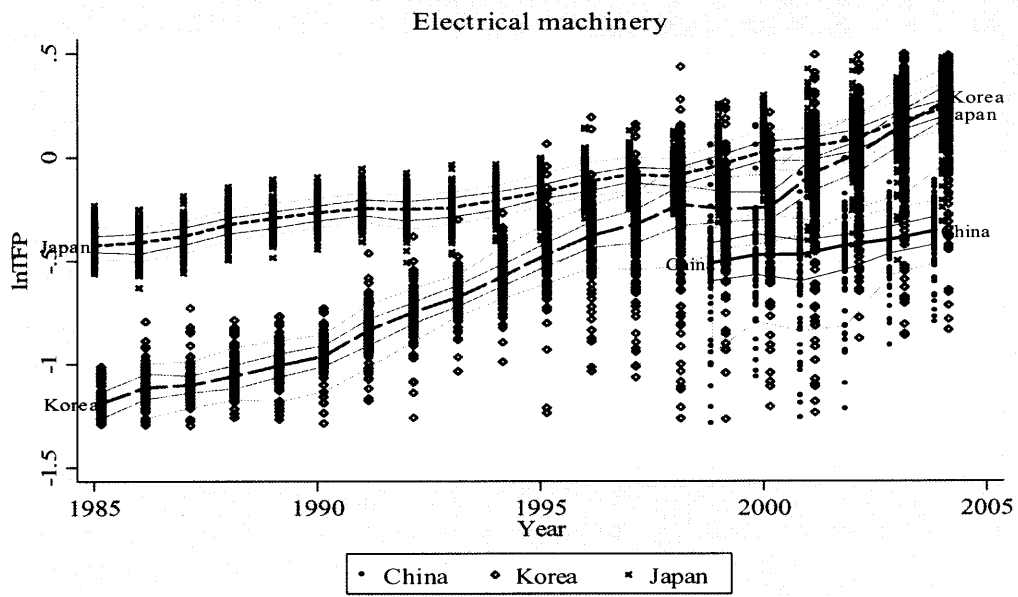


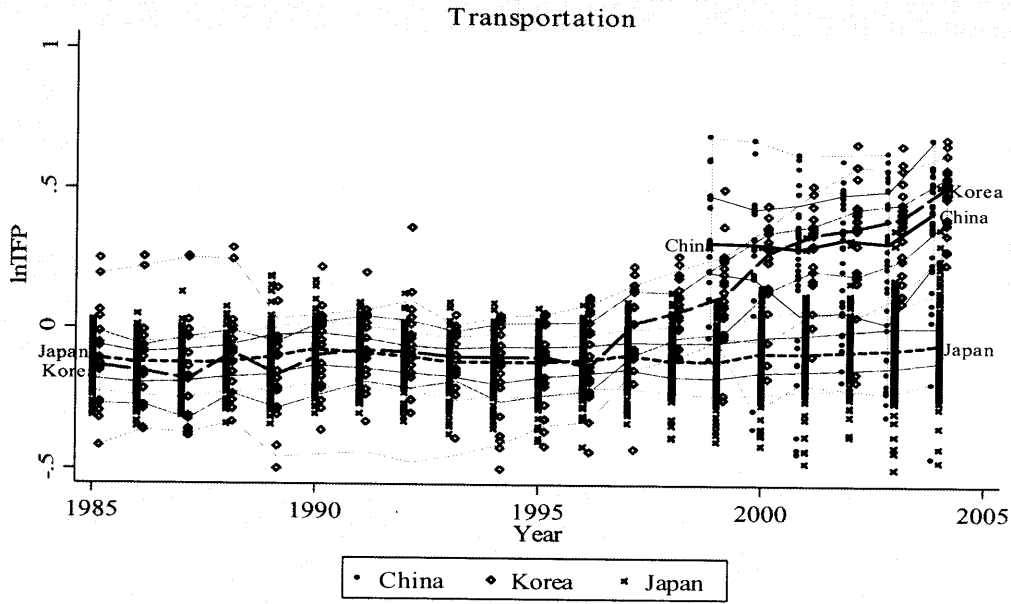












2.3 Decomposition of industry-level TFP for Japan, Korea, and China: Resource allocation and productivity

We can calculate the industry-level TFP by aggregating the firm-level TFP using the following equation (Bailey, Hulten and Campbell 1992):¹⁰

$$\ln TFP_t = \sum_f \theta_{ft} \ln TFP_{ft} \quad (1)$$

where θ_{ft} denotes firm f 's sales share in year t in that industry. Equation (1), though a subscript representing industry is omitted, indicates that the industry-level TFP can be calculated as a weighted average of firm-level TFP using the sales share as a weight. Moreover, by decomposing the industry-level TFP using equation (2) below, we can analyze the determinants of industry-level TFP growth (Olley and Pakes 1996; Bartelsman, Haltiwanger and Scarpetta 2004, 2005):

$$\ln TFP_t = (1/N_t) \sum_f \ln TFP_{ft} + \sum_f (\theta_{ft} - \bar{\theta}_t) (\ln TFP_{ft} - \overline{\ln TFP_{ft}}) \quad (2)$$

where N_t is the number of firms in year t in that industry and the first term on the right-hand side is the simple average of firm-level TFP. The variables with an upper bar indicate the simple average of the sales share and the simple average of firm-level TFP, respectively. That is, the second term of the right-hand side is the deviation from the industry mean of the sales share multiplied by the deviation from the industry mean of firm-level TFP, which can be called the resource allocation effect. In other words, a boost in industry-level TFP is realized when firms

¹⁰ Aggregated labor productivity is usually calculated as a weighted average of firm-level labor productivity using the employment share as a weight.

with higher TFP hold a larger share in the industry and firms with lower TFP hold a smaller share. Moreover, the above two equations show that the resource allocation effect is the difference between the weighted average of firm-level TFP and the simple average of firm-level TFP.

For the 12 major industries analyzed here, the annual growth rate of industry-level TFP (the weighted average of firm-level TFP) and the improvement in the resource allocation effect are presented in Table 4.¹¹ In Japan, most industries, with the notable exception of the electrical machinery industry, show a very low level of TFP growth, although the TFP growth rate is higher for the period 1999-2004 than for other periods. In Korea, the electrical machinery industry achieved the highest TFP growth rate. Excluding the period from 1995-1999 which was affected by the economic crisis, it seems that the gap between the TFP growth rate of the electrical machinery industry and those of other industries has been expanding in Korea. As for China, the TFP growth rate has been relatively high for industries such as stone, clay and glass products, non-electrical machinery, electrical machinery, motor vehicles, and transportation. However, the annual TFP growth rate in the Chinese electrical machinery industry at 2.8% for the period 1999-2004 was relatively low compared with corresponding rates of 5.2% for Japan and 11.0% for Korea.

The improvement in the resource allocation effect can be calculated as the difference between the resource allocation effects at the beginning and at the end of the period. In Table 4, figures in parentheses indicate the percentage contribution of the improvement in the resource allocation effect to the annual TFP growth rate. Moreover, shaded figures represent positive contributions to the annual TFP growth rate. In both Japan and Korea, the positive effect of the improvement of allocative efficiency appears to have become more pervasive in recent years (1999-2004), which may reflect the fact that the market environment has become more competitive.¹² In Korea, however, although the positive contribution of the allocative efficiency effect has been larger in recent years, in many industries the magnitude of the TFP growth rate has been much smaller than in the earlier period (1985-95). This observation suggests that overall TFP growth has stalled in many Korean industries, although competitive pressures did ensure that TFP growth continued to some extent. It seems that, in Korea, the within-firm TFP improvement effect (the first term on the right-hand side of equation (2)) has become smaller in recent years in many industries (the electrical machinery industry is a notable exception), which is an issue that deserves further

¹¹ For industry-level TFP growth rates and the improvement in the resource allocation effect for all industries, see Appendix Table 1.

¹² For the case of Japan, Kim, Kwon and Fukao (2007) conducted a TFP decomposition analysis and found that the resource allocation effect was relatively small during the 1980s but has gradually increased since the mid-1990s. Their findings are consistent with our results in Table 4. In the case of Korea, after the financial crisis in the late 1990s, various structural reforms were carried out and created a more competitive market environment.

investigation. In the case of China, we find a relatively large allocative efficiency effect in many industries. This suggests that Chinese firms can easily increase or lose sales share in the rapidly growing market. In addition, we should note that the small sample size and the relatively low quality of the Chinese data may produce results with large measurement errors.

Table 4. Annual TFP growth rate and improvement of allocative efficiency: major industries

	Japan		Korea		China	
	1985-95	1995-99	1985-95	1995-99	1985-95	1995-99
Construction	-0.57 (-33.4)	-0.31 (29.8)	-4.88 (15.7)	-0.79 (185.4)	-1.06 (-29.5)	-1.74 (-105.1)
Food and kindred products	-0.04 (-13.6)	-0.21 (81.2)	3.78 (6.3)	-1.41 (2.0)	1.91 (45.9)	-0.29 (485.8)
Textile mill products	-0.60 (16.9)	-0.05 (-81.5)	3.04 (10.4)	1.98 (20.7)	1.65 (32.3)	0.16 (191.7)
Apparel	-0.57 (-5.7)	-0.63 (-49.5)	4.22 (0.1)	0.37 (-30.2)	2.65 (9.5)	0.80 (-299.3)
Paper and allied products	-0.22 (-47.7)	-0.42 (-57.3)	2.16 (-24.6)	-3.89 (-14.8)	1.57 (44.1)	1.47 (79.1)
Chemicals	0.81 (4.7)	1.58 (16.4)	2.44 (3.5)	1.98 (13.0)	-0.97 (2.2)	0.60 (32.7)
Stone, clay and glass products	-0.20 (-64.7)	0.74 (34.9)	3.03 (-16.4)	0.27 (56.0)	3.48 (23.6)	3.70 (33.6)
Primary metals	0.70 (47.6)	0.69 (54.8)	2.78 (5.8)	-1.08 (-50.1)	-2.85 (21.4)	-0.28 (273.2)
Non-electrical machinery	0.68 (43.7)	-0.15 (-136.4)	3.75 (5.7)	-0.94 (-96.5)	1.65 (72.1)	2.71 (-37.9)
Electrical machinery	2.67 (5.4)	3.18 (-2.1)	9.23 (21.1)	0.72 (-647.2)	11.05 (10.6)	2.83 (-43.8)
Motor vehicles	0.74 (-23.9)	0.29 (173.0)	4.84 (-1.0)	1.03 (-142.1)	1.39 (-38.2)	2.78 (73.1)
Transportation	1.07 (-5.8)	0.83 (64.5)	3.59 (-16.0)	2.64 (-133.4)	9.15 (20.0)	4.94 (72.1)

Notes: The left column for each period shows the annual TFP growth rate (%), while the figures in parentheses refer to the percentage contribution of improvements in allocative efficiency to annual TFP growth. Shaded figures indicate a positive contribution to annual TFP growth.

3. Heterogeneity of Firms: Is Productivity Dispersion Pervasive?

In this section, we examine whether the productivity dispersion within an industry has been increasing over time. Furthermore, we analyze productivity rankings within an industry and investigate whether these rankings have changed frequently.

First, we conduct a simple regression analysis in order to check whether there has been an increase in productivity dispersion. We estimate the following equation:

$$D2575_{it}=a+b*(Time\ Trend) \quad (3)$$

where $D2575_{it}$ is the distance between the top and the bottom quartile in the distribution of firm TFP levels in industry i in year t , or the distance between the top and the bottom quartile of firm TFP growth rates in industry i in year t . By regressing the distance on a time trend, we examine whether the productivity dispersion has been increasing year by year.¹³ The regression results are shown in Table 5. However, we do not conduct this regression for China due to the small sample size.

In Table 5, the coefficient on the time trend variable is significantly positive in many industries, suggesting that the dispersion of both firm TFP levels and firm TFP growth rates has been increasing year by year. The increase in the dispersion of firm TFP levels indicates that the productivity gap between high-performing and low-performing firms has been getting wider. In the case of Japan, the dispersion of TFP levels has been widening in 15 industries compared to 4 where it has been significantly narrowing. On the other hand, in the case of Korea, the dispersion of TFP levels has been widening in 7 industries and narrowing in 5 industries. As for the dispersion of firm TFP growth rates, this has increased in many industries both in Japan and Korea. The increase in the dispersion of firm TFP growth rates can be interpreted as indicating that there are increasing ups and down in the TFP levels within an industry. Although the number of industries where we see a significant positive coefficient on the time trend variable is greater for Japan than for Korea, the magnitude of the coefficient tends to be larger in Korea. This result implies that in some industries in Korea, there were larger ups and downs in the TFP level than in Japan.

Moreover, in the majority of industries which show a widening dispersion of TFP levels, we also find a significant widening in the dispersion of firm TFP growth rates: out of the 15 industries in Japan that show a widening dispersion of TFP levels, 9 also show a widening dispersion of TFP growth rates, while in Korea it is 6 out of 7.

¹³ The standard deviations of firm TFP levels and firm TFP growth rates can be used instead of the distance between the first and the last quartiles. However, in order to mitigate the effect of outliers, we use the distance between the first and the last quartile.

Table 5. Coefficients on the time trend

Dependent variable: distance between the first quartile and the fourth quartile of the TFP level or TFP growth rate

Industry	Distance of TFP level		Distance of TFP growth rate	
	Japan	Korea	Japan	Korea
1 Agriculture	0.0072 ***	0.0077 **	-0.0007	0.0044
2 Coal mining	0.0005	n.a.	0.0012 **	n.a.
3 Metal and nonmetallic mining	0.0040 *	n.a.	-0.0003	n.a.
4 Oil and gas extraction	-0.0206 ***	n.a.	-0.0111	n.a.
5 Construction	-0.0022 ***	-0.0068 ***	0.0003 **	-0.0008
6 Food and kindred products	0.0009 ***	0.0030 ***	0.0002 **	0.0015 ***
7 Textile mill products	-0.00004	0.0023	-0.00003	0.0007
8 Apparel	0.0020 ***	0.0013	0.0008 **	0.0035 ***
9 Lumber and wood	-0.0012 *	-0.0063	-0.0005	-0.0036
10 Furniture and fixtures	0.0031 ***	-0.0007	0.0006 *	-0.0006
11 Paper and allied products	0.0002	-0.0020	0.0001	0.0012
12 Printing, publishing and allied products	0.0042 ***	-0.0273 *	0.0015 ***	-0.0043
13 Chemicals	0.0012 ***	-0.0005	0.0004 **	0.0016 ***
14 Petroleum and coal products	0.0018 ***	0.0005	-0.0002	0.0006
15 Leather	0.0024	0.0036 **	0.0032 *	0.0036 **
16 Stone, clay and glass products	0.0005	0.0007	0.0004	-0.0002
17 Primary metals	-0.0001	-0.0003	0.0003	0.00001
18 Fabricated metals	0.0009 **	-0.0024	0.0004 **	0.0005
19 Non-electrical machinery	0.0001	0.0044 ***	0.0003	0.0034 **
20 Electrical machinery	0.0005	0.0032 ***	0.0013 **	0.0041 ***
21 Motor vehicles	0.0002	-0.0021 **	0.0003 *	-0.0003
22 Transportation equipment and ordnance	0.0001	-0.0011	0.0002	-0.0011
23 Instruments	0.0001	0.0071 ***	0.0003	0.0058 ***
24 Rubber and misc. plastics	0.0018 ***	0.0018 ***	0.0008 ***	0.0017 *
25 Misc. manufacturing	0.0024 **	-0.0004	0.0012 ***	-0.0001
26 Transportation	0.0009 *	-0.0032 **	-0.0003 *	-0.0031 *
27 Communication	0.0008	-0.0263	0.0011	-0.0193
28 Electrical utilities	0.0022 ***	n.a.	-0.0001	n.a.
29 Gas utilities	-0.0067 ***	-0.0309 ***	-0.0007	-0.0122 ***
30 Trade	0.0015 ***	0.0017	0.0007	0.0026 ***
31 Finance, insurance and real estate	-0.0003	n.a.	-0.0012	n.a.
32 Other private services	0.0042 ***	-0.0046	0.0008 ***	0.0074 ***
33 Public service	n.a.	n.a.	n.a.	n.a.

Notes: The number of observations for each regression is 20 for the TFP level regressions and 19 for the TFP growth regressions.

n.a. = not applicable.

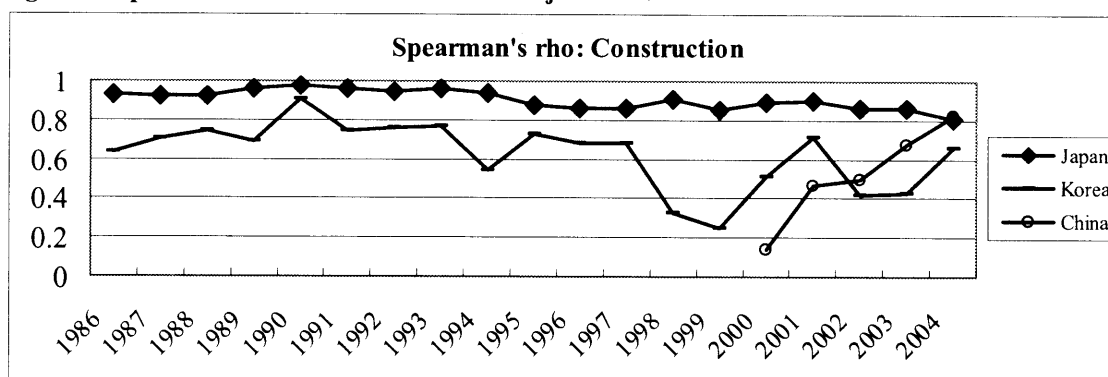
***, **, * significant at 1%, 5%, 10%, respectively.

The above observations remind us of the four models of evolution of productivity distribution suggested by Baily, Hulten and Campbell (1992: p. 196, Figure 1). The first model suggests that the distribution of productivity across plants is determined by random shocks or data errors in the level of productivity, assuming the existence of a common path of trend productivity growth for all the plants in an industry. The second model attributes the distribution of productivity to a

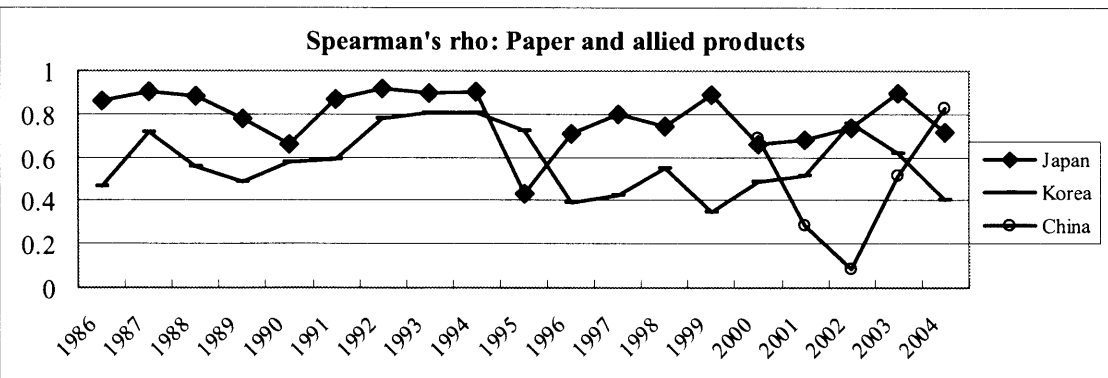
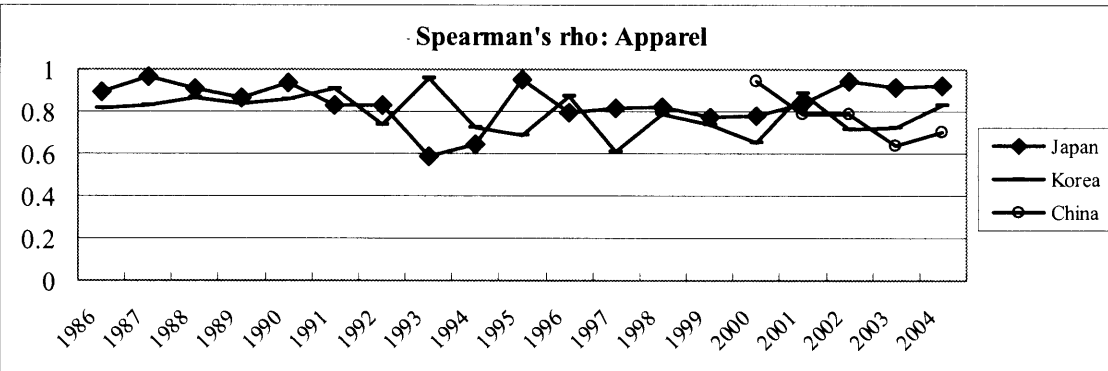
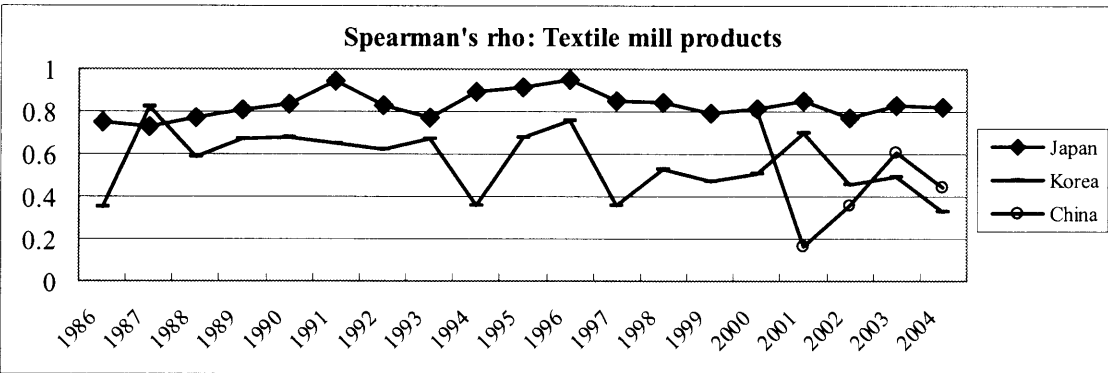
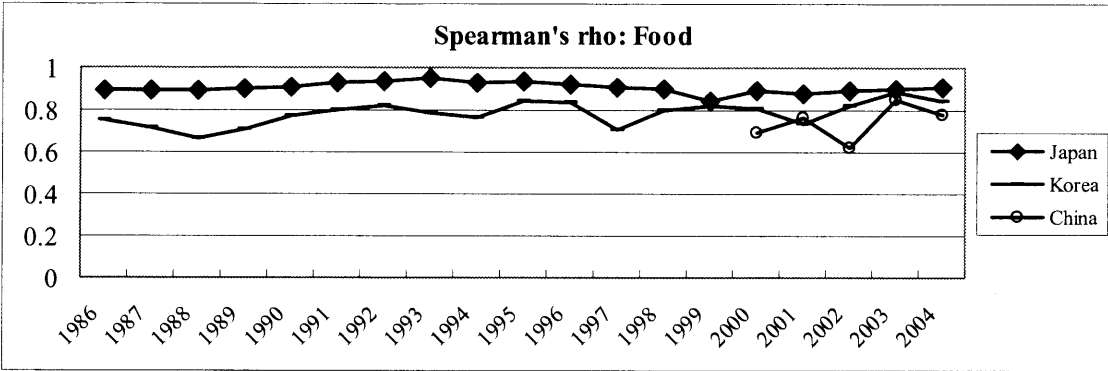
random draw in the growth of productivity rather than in the level. In the third model, the distribution arises as a result of plants of different vintages, assuming that when a plant is built it embodies a particular vintage of technology. The fourth model suggests that the distribution reflects permanent plant heterogeneity. In the remainder of this section, we analyze the rankings of firm TFP levels and their transition over time for major industries in order to identify which model best describes the pattern of evolution of productivity dispersion in the three countries.

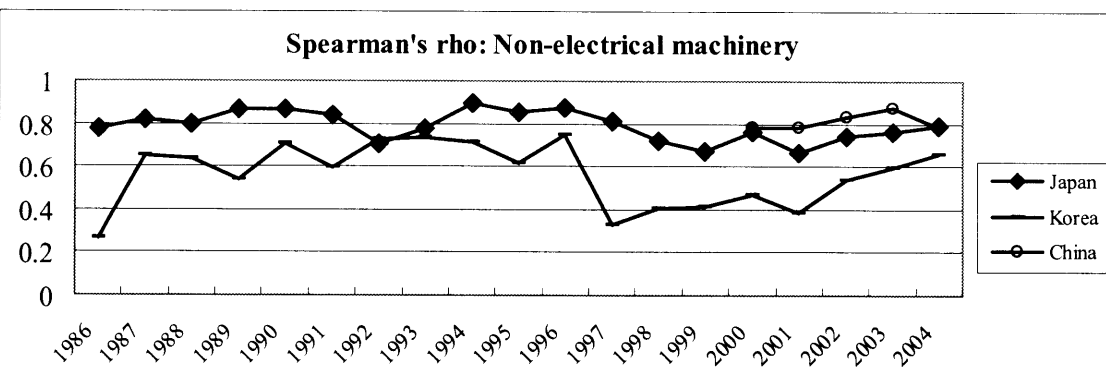
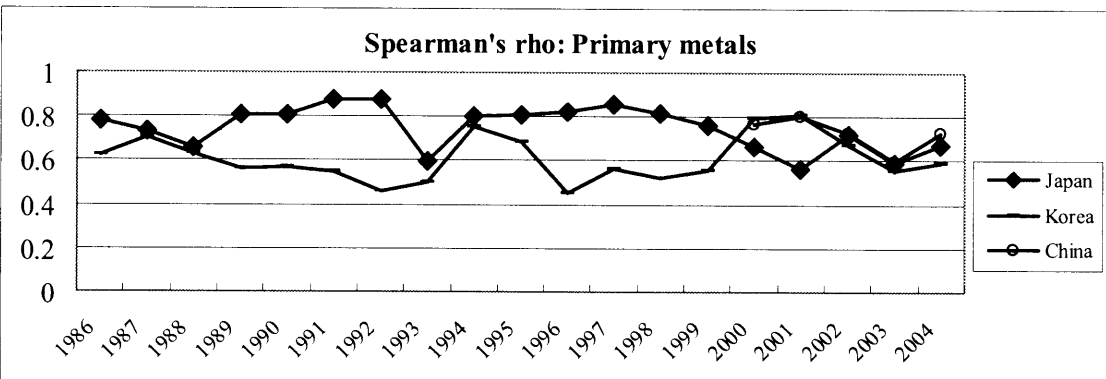
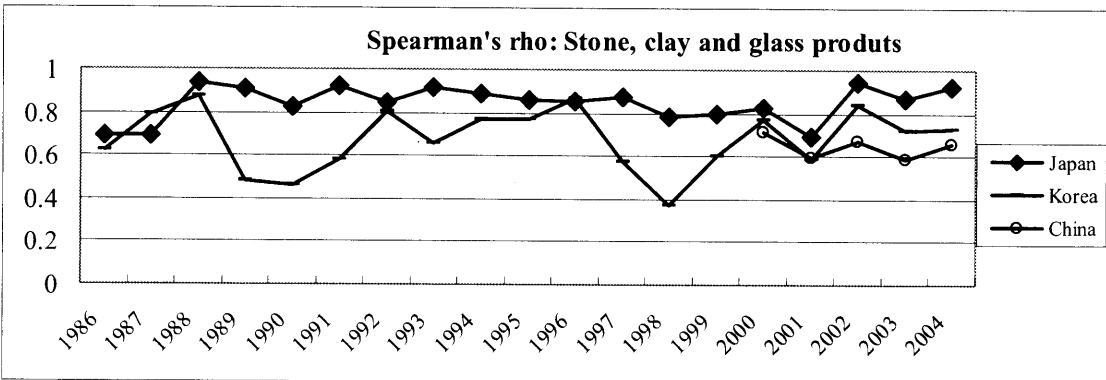
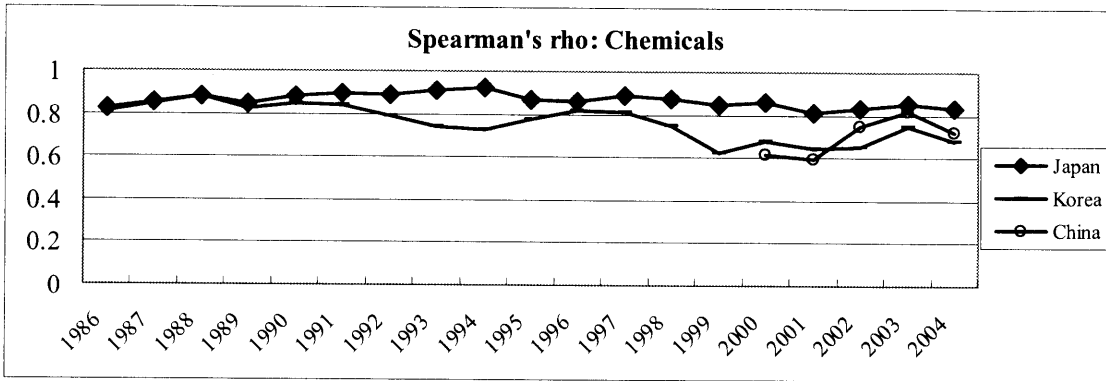
We calculate Spearman's rank correlation coefficients (Spearman's rho) between year $t-1$ and year t in order to examine whether firms' rankings in terms of their TFP level change frequently within an industry. If Spearman's rho is close to 1, this indicates that rankings in terms of the TFP level within an industry are less likely to change from year $t-1$ to t . On the other hand, a Spearman's rho close to zero indicates that the rankings changed almost completely. The yearly Spearman's rhos for the 12 major industries are shown in Figure 2. As can be seen, Spearman's rho is greater than 0.8 in many industries in Japan, suggesting that TFP level rankings tend to be stable. On the other hand, for Korean industries, Spearman's rho tends to be much smaller, suggesting frequent changes in rankings. For Chinese industries, meanwhile, Spearman's rho is as high as that for Japan in industries such as primary metals, non-electrical machinery, electrical machinery, and motor vehicles. These results suggest that the productivity distribution is more likely to be attributable to a random draw in the case of Korea, while it is more likely to be attributable to permanent firm heterogeneity in the case of Japan.¹⁴

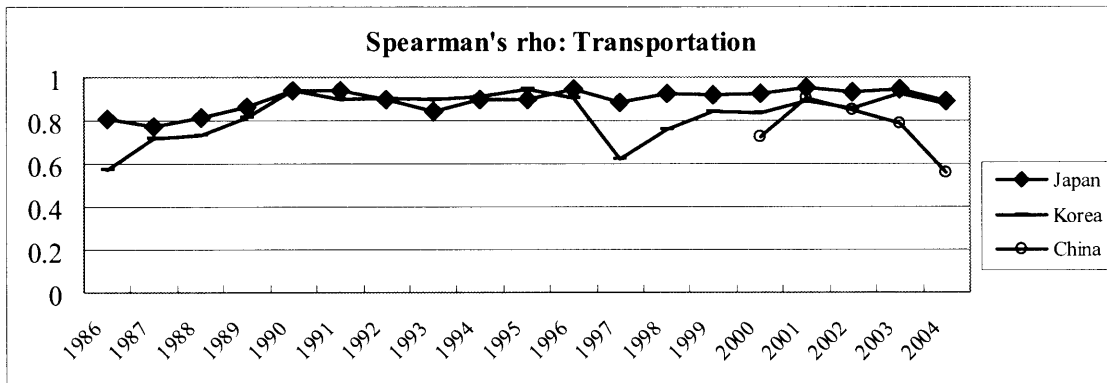
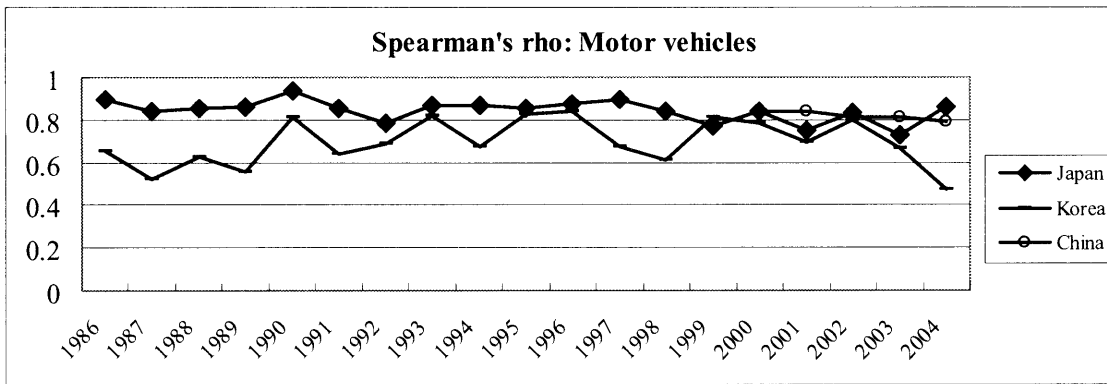
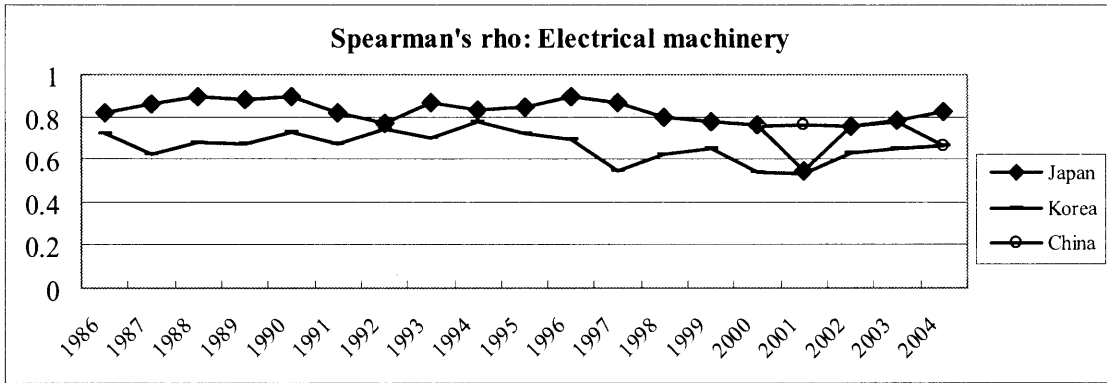
Figure 2. Spearman's rank correlation for major industries



¹⁴ It is difficult to find a clear pattern in the case of China, which may be attributable to measurement errors and the relatively small number of observations.







Furthermore, in order to scrutinize the change in TFP rankings, we calculate a transition matrix of the rankings for the chemical and the electrical machinery industries, where we have a relatively large number of observations. Table 6 shows the transition matrix of the TFP rankings for three periods – 1985-1995, 1995-1999, and 1999-2004 – for Japan, Korea, and China. Hereafter, each transition matrix is denoted as A_{8595J} , A_{9599J} , A_{9904J} , and so on. The subscript J here refers to Japan, while, likewise, K and C refer to Korea and China, respectively. Each row of a transition matrix shows the decile as of the beginning of the period, while the each column shows the decile as of the end of the period. In other words, factor a_{ij} (the i^{th} row and the j^{th} column) in the transition matrix indicates the ratio of the number of firms which were in the i^{th} decile of the TFP distribution as of the beginning of the period and moved to the j^{th} decile as of the end of the

period to the total number of firms which were in the i^{th} decile as of the beginning of the period. Therefore, the diagonal factors of the matrix show the share of the number of firms which stayed in the same decile during the period. The factors above the diagonal line show the share of the number of firms which moved to an upper decile while the factors below the diagonal line show the share of the number of firms which moved to a lower decile.

Looking at the transition matrices for the Japanese chemical industry, approximately 30% of firms in the first decile (the lowest 10% group) as of the beginning of each period stayed in the first decile as of the end of each period. Moreover, 40-65% of firms in the 10th decile as of the beginning of each period stayed in the 10th decile (the highest 10% group) as of the end of each period. On the other hand, in the cases of the Korean and the Chinese chemical industries, the share of firms staying in the first decile during each period was around 14-23%, while the share of firms staying in the 10th decile was around 23-33%. Thus, compared with the cases of Korea and China, higher-TFP firms in the Japanese chemical industry were more likely to stay in the higher-TFP group and lower-TFP firms were more likely to stay in the lower-TFP group.

In the case of the Japanese electrical machinery industry, 55.6% (54.2%) of firms in the first decile (the 10th decile) as of 1999 stayed in the first decile (the 10th decile) as of 2004. Comparing A_{8595J} with A_{9599J} and A_{9904J} , ranking changes become less frequent over time. Contrary to the Japanese case, only 16.0% (6.7%) of firms in the first decile (the 10th decile) as of 1999 stayed in the first decile (the 10th decile) as of 2004 in the case of Korea. As for China, 16.7% (28.6%) of firms in the first decile (the 10th decile) as of 1999 stayed in the first decile (the 10th decile) as of 2004. It follows that the TFP ranking changed relatively frequently in the case of the Korean electrical machinery industry.

Table 6. TFP level transition matrixes

(a) Japan: Chemicals 1985-1995

1995		10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
1985	10th	33.3%	20.0%	13.3%	6.7%	0.0%	13.3%	6.7%	0.0%	0.0%	6.7%
	20th	21.4%	42.9%	7.1%	14.3%	0.0%	7.1%	0.0%	7.1%	0.0%	0.0%
	30th	0.0%	13.3%	13.3%	20.0%	26.7%	6.7%	0.0%	13.3%	6.7%	0.0%
	40th	14.3%	14.3%	28.6%	14.3%	14.3%	0.0%	0.0%	7.1%	0.0%	7.1%
	50th	14.3%	14.3%	28.6%	7.1%	14.3%	7.1%	7.1%	0.0%	7.1%	0.0%
	60th	20.0%	13.3%	6.7%	13.3%	6.7%	6.7%	20.0%	6.7%	6.7%	0.0%
	70th	13.3%	0.0%	6.7%	0.0%	13.3%	26.7%	26.7%	6.7%	0.0%	6.7%
	80th	0.0%	0.0%	14.3%	14.3%	7.1%	7.1%	28.6%	28.6%	0.0%	0.0%
	90th	0.0%	0.0%	0.0%	6.7%	13.3%	33.3%	20.0%	13.3%	6.7%	6.7%
	100th	6.7%	0.0%	0.0%	6.7%	0.0%	13.3%	6.7%	6.7%	20.0%	40.0%

(b) Japan: Chemicals 1995-1999

1999		10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
1995	10th	36.8%	15.8%	21.1%	15.8%	5.3%	5.3%	0.0%	0.0%	0.0%	0.0%
	20th	33.3%	23.8%	19.0%	9.5%	4.8%	4.8%	4.8%	0.0%	0.0%	0.0%
	30th	5.0%	20.0%	20.0%	15.0%	20.0%	10.0%	5.0%	0.0%	5.0%	0.0%
	40th	9.5%	14.3%	14.3%	9.5%	19.0%	9.5%	0.0%	23.8%	0.0%	0.0%
	50th	15.8%	10.5%	15.8%	15.8%	10.5%	5.3%	10.5%	5.3%	10.5%	0.0%
	60th	0.0%	4.8%	9.5%	14.3%	14.3%	19.0%	19.0%	9.5%	9.5%	0.0%
	70th	5.0%	5.0%	0.0%	15.0%	10.0%	10.0%	30.0%	10.0%	10.0%	5.0%
	80th	0.0%	5.6%	5.6%	5.6%	11.1%	11.1%	11.1%	33.3%	11.1%	5.6%
	90th	0.0%	4.8%	0.0%	4.8%	4.8%	19.0%	14.3%	9.5%	28.6%	14.3%
	100th	5.9%	0.0%	0.0%	5.9%	0.0%	0.0%	5.9%	0.0%	17.6%	64.7%

(c) Japan: Chemicals 1999-2004

2004		10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
1999	10th	27.8%	16.7%	22.2%	16.7%	0.0%	0.0%	5.6%	5.6%	5.6%	0.0%
	20th	20.0%	20.0%	15.0%	15.0%	0.0%	15.0%	15.0%	0.0%	0.0%	0.0%
	30th	15.8%	21.1%	5.3%	15.8%	10.5%	21.1%	5.3%	5.3%	0.0%	0.0%
	40th	4.8%	19.0%	23.8%	4.8%	23.8%	4.8%	9.5%	9.5%	0.0%	0.0%
	50th	0.0%	10.5%	10.5%	26.3%	10.5%	10.5%	5.3%	21.1%	5.3%	0.0%
	60th	5.3%	10.5%	10.5%	10.5%	5.3%	15.8%	21.1%	5.3%	10.5%	5.3%
	70th	5.0%	0.0%	10.0%	10.0%	10.0%	25.0%	15.0%	15.0%	10.0%	0.0%
	80th	10.5%	5.3%	5.3%	5.3%	15.8%	0.0%	5.3%	26.3%	15.8%	10.5%
	90th	0.0%	4.8%	4.8%	0.0%	23.8%	14.3%	9.5%	14.3%	23.8%	4.8%
	100th	0.0%	0.0%	0.0%	0.0%	5.0%	5.0%	10.0%	5.0%	20.0%	55.0%

(d) Korea: Chemicals 1985-1995

1995

1985	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	18.2%	9.1%	9.1%	18.2%	9.1%	9.1%	18.2%	0.0%	0.0%	9.1%
20th	10.0%	10.0%	30.0%	0.0%	0.0%	10.0%	20.0%	20.0%	0.0%	0.0%
30th	10.0%	20.0%	0.0%	20.0%	10.0%	0.0%	20.0%	10.0%	0.0%	10.0%
40th	10.0%	20.0%	0.0%	30.0%	20.0%	10.0%	0.0%	0.0%	0.0%	10.0%
50th	0.0%	0.0%	9.1%	18.2%	9.1%	9.1%	9.1%	27.3%	9.1%	9.1%
60th	0.0%	0.0%	22.2%	0.0%	22.2%	0.0%	0.0%	11.1%	44.4%	0.0%
70th	0.0%	0.0%	30.0%	20.0%	10.0%	10.0%	0.0%	0.0%	30.0%	0.0%
80th	0.0%	0.0%	10.0%	0.0%	10.0%	0.0%	20.0%	20.0%	10.0%	30.0%
90th	20.0%	20.0%	0.0%	0.0%	10.0%	20.0%	0.0%	10.0%	10.0%	10.0%
100th	0.0%	0.0%	0.0%	0.0%	0.0%	10.0%	10.0%	20.0%	30.0%	30.0%

(e) Korea: Chemicals 1995-1999

1999

1995	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	15.4%	38.5%	15.4%	0.0%	7.7%	7.7%	15.4%	0.0%	0.0%	0.0%
20th	21.4%	7.1%	21.4%	14.3%	7.1%	21.4%	0.0%	7.1%	0.0%	0.0%
30th	0.0%	14.3%	14.3%	21.4%	21.4%	7.1%	7.1%	7.1%	7.1%	0.0%
40th	7.1%	7.1%	7.1%	21.4%	14.3%	21.4%	7.1%	14.3%	0.0%	0.0%
50th	0.0%	7.7%	7.7%	7.7%	38.5%	15.4%	0.0%	7.7%	15.4%	0.0%
60th	7.7%	7.7%	7.7%	7.7%	15.4%	0.0%	15.4%	7.7%	7.7%	23.1%
70th	14.3%	7.1%	7.1%	14.3%	0.0%	7.1%	14.3%	28.6%	7.1%	0.0%
80th	7.1%	0.0%	0.0%	14.3%	0.0%	0.0%	7.1%	14.3%	21.4%	35.7%
90th	14.3%	14.3%	0.0%	0.0%	7.1%	7.1%	21.4%	14.3%	14.3%	7.1%
100th	0.0%	0.0%	15.4%	0.0%	0.0%	15.4%	23.1%	0.0%	23.1%	23.1%

(f) Korea: Chemicals 1999-2004

2004

1999	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	23.1%	23.1%	0.0%	7.7%	7.7%	7.7%	7.7%	0.0%	7.7%	15.4%
20th	20.0%	6.7%	26.7%	6.7%	20.0%	0.0%	6.7%	6.7%	6.7%	0.0%
30th	7.1%	7.1%	7.1%	14.3%	14.3%	21.4%	21.4%	7.1%	0.0%	0.0%
40th	14.3%	28.6%	7.1%	7.1%	0.0%	14.3%	14.3%	14.3%	0.0%	0.0%
50th	0.0%	12.5%	6.3%	18.8%	6.3%	25.0%	18.8%	6.3%	6.3%	0.0%
60th	7.1%	7.1%	7.1%	7.1%	35.7%	7.1%	7.1%	0.0%	14.3%	7.1%
70th	25.0%	12.5%	0.0%	12.5%	12.5%	6.3%	6.3%	6.3%	6.3%	12.5%
80th	6.7%	13.3%	20.0%	0.0%	6.7%	0.0%	20.0%	13.3%	6.7%	13.3%
90th	0.0%	0.0%	13.3%	0.0%	6.7%	0.0%	6.7%	26.7%	20.0%	26.7%
100th	0.0%	0.0%	0.0%	7.1%	0.0%	21.4%	0.0%	21.4%	21.4%	28.6%

(g) China: Chemicals 1999-2004

2004

1999	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	14.3%	0.0%	14.3%	0.0%	0.0%	14.3%	14.3%	0.0%	14.3%	28.6%
20th	22.2%	11.1%	0.0%	11.1%	11.1%	44.4%	0.0%	0.0%	0.0%	0.0%
30th	18.2%	9.1%	9.1%	18.2%	27.3%	9.1%	0.0%	9.1%	0.0%	0.0%
40th	0.0%	10.0%	30.0%	10.0%	20.0%	10.0%	0.0%	20.0%	0.0%	0.0%
50th	0.0%	0.0%	10.0%	70.0%	10.0%	10.0%	0.0%	0.0%	0.0%	0.0%
60th	18.2%	9.1%	18.2%	18.2%	0.0%	9.1%	27.3%	0.0%	0.0%	0.0%
70th	0.0%	11.1%	11.1%	0.0%	11.1%	0.0%	22.2%	33.3%	11.1%	0.0%
80th	11.1%	22.2%	11.1%	0.0%	11.1%	0.0%	22.2%	0.0%	0.0%	22.2%
90th	22.2%	11.1%	0.0%	11.1%	0.0%	0.0%	0.0%	22.2%	22.2%	11.1%
100th	11.1%	11.1%	0.0%	0.0%	0.0%	0.0%	11.1%	11.1%	22.2%	33.3%

(h) Japan: Electrical Machinery 1985-1995

1995

1985	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	18.8%	18.8%	12.5%	12.5%	0.0%	12.5%	12.5%	6.3%	0.0%	6.3%
20th	26.7%	13.3%	33.3%	13.3%	6.7%	0.0%	0.0%	6.7%	0.0%	0.0%
30th	7.7%	23.1%	7.7%	15.4%	23.1%	7.7%	7.7%	7.7%	0.0%	0.0%
40th	12.5%	18.8%	6.3%	6.3%	6.3%	0.0%	12.5%	12.5%	12.5%	12.5%
50th	6.7%	13.3%	20.0%	20.0%	0.0%	0.0%	0.0%	6.7%	6.7%	26.7%
60th	0.0%	0.0%	0.0%	0.0%	26.7%	26.7%	26.7%	6.7%	13.3%	0.0%
70th	0.0%	12.5%	6.3%	6.3%	18.8%	0.0%	31.3%	12.5%	12.5%	0.0%
80th	6.7%	0.0%	6.7%	6.7%	0.0%	33.3%	13.3%	13.3%	6.7%	13.3%
90th	0.0%	6.7%	6.7%	20.0%	0.0%	13.3%	6.7%	26.7%	20.0%	0.0%
100th	0.0%	7.1%	7.1%	7.1%	14.3%	21.4%	7.1%	7.1%	7.1%	21.4%

(i) Japan: Electrical Machinery 1995-1999

1999

1995	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	27.3%	27.3%	9.1%	13.6%	0.0%	4.5%	4.5%	9.1%	4.5%	0.0%
20th	25.0%	25.0%	16.7%	0.0%	20.8%	0.0%	4.2%	8.3%	0.0%	0.0%
30th	22.7%	18.2%	18.2%	9.1%	9.1%	0.0%	9.1%	9.1%	4.5%	0.0%
40th	4.3%	17.4%	17.4%	21.7%	4.3%	8.7%	13.0%	8.7%	4.3%	0.0%
50th	17.4%	8.7%	21.7%	21.7%	8.7%	13.0%	8.7%	0.0%	0.0%	0.0%
60th	4.2%	8.3%	8.3%	8.3%	16.7%	12.5%	16.7%	16.7%	8.3%	0.0%
70th	4.8%	0.0%	9.5%	14.3%	19.0%	14.3%	19.0%	4.8%	14.3%	0.0%
80th	0.0%	0.0%	4.3%	4.3%	26.1%	17.4%	17.4%	13.0%	17.4%	0.0%
90th	0.0%	4.2%	0.0%	4.2%	12.5%	20.8%	20.8%	16.7%	12.5%	8.3%
100th	4.3%	0.0%	4.3%	8.7%	0.0%	0.0%	0.0%	4.3%	34.8%	43.5%

(j) Japan: Electrical Machinery 1999-2004

2004

1999	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	55.6%	5.6%	11.1%	5.6%	5.6%	11.1%	0.0%	0.0%	0.0%	5.6%
20th	3.8%	26.9%	19.2%	11.5%	7.7%	15.4%	0.0%	3.8%	3.8%	7.7%
30th	14.3%	23.8%	14.3%	14.3%	4.8%	9.5%	4.8%	4.8%	4.8%	4.8%
40th	9.1%	4.5%	27.3%	18.2%	9.1%	13.6%	0.0%	9.1%	4.5%	4.5%
50th	4.0%	12.0%	4.0%	20.0%	12.0%	24.0%	20.0%	4.0%	0.0%	0.0%
60th	4.0%	4.0%	16.0%	12.0%	16.0%	0.0%	20.0%	16.0%	8.0%	4.0%
70th	13.0%	0.0%	4.3%	17.4%	8.7%	21.7%	0.0%	21.7%	13.0%	0.0%
80th	7.7%	7.7%	7.7%	3.8%	19.2%	3.8%	26.9%	7.7%	15.4%	0.0%
90th	0.0%	8.3%	8.3%	0.0%	8.3%	4.2%	25.0%	16.7%	25.0%	4.2%
100th	4.2%	0.0%	0.0%	4.2%	4.2%	4.2%	12.5%	8.3%	8.3%	54.2%

(k) Korea: Electrical Machinery 1985-1995

1995										
1985	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	12.5%	25.0%	12.5%	25.0%	12.5%	0.0%	12.5%	0.0%	0.0%	0.0%
20th	0.0%	16.7%	16.7%	0.0%	50.0%	16.7%	0.0%	0.0%	0.0%	0.0%
30th	0.0%	14.3%	28.6%	14.3%	0.0%	28.6%	0.0%	14.3%	0.0%	0.0%
40th	14.3%	0.0%	0.0%	0.0%	28.6%	42.9%	14.3%	0.0%	0.0%	0.0%
50th	0.0%	14.3%	0.0%	14.3%	14.3%	0.0%	14.3%	42.9%	0.0%	0.0%
60th	0.0%	0.0%	14.3%	0.0%	0.0%	42.9%	0.0%	28.6%	0.0%	14.3%
70th	0.0%	0.0%	14.3%	14.3%	0.0%	14.3%	14.3%	28.6%	14.3%	0.0%
80th	0.0%	0.0%	28.6%	28.6%	14.3%	28.6%	0.0%	0.0%	0.0%	0.0%
90th	0.0%	0.0%	14.3%	14.3%	0.0%	0.0%	14.3%	42.9%	14.3%	0.0%
100th	16.7%	0.0%	0.0%	0.0%	0.0%	0.0%	16.7%	0.0%	33.3%	33.3%

(l) Korea: Electrical Machinery 1995-1999

1999										
1995	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	0.0%	22.2%	27.8%	11.1%	5.6%	11.1%	5.6%	5.6%	5.6%	5.6%
20th	5.0%	15.0%	15.0%	10.0%	10.0%	20.0%	15.0%	5.0%	0.0%	5.0%
30th	21.1%	5.3%	15.8%	5.3%	10.5%	15.8%	10.5%	5.3%	5.3%	5.3%
40th	5.0%	10.0%	15.0%	10.0%	15.0%	5.0%	25.0%	10.0%	5.0%	0.0%
50th	5.0%	10.0%	5.0%	25.0%	5.0%	10.0%	20.0%	10.0%	5.0%	5.0%
60th	20.0%	10.0%	5.0%	10.0%	15.0%	20.0%	5.0%	5.0%	10.0%	0.0%
70th	5.3%	5.3%	15.8%	15.8%	10.5%	15.8%	10.5%	5.3%	5.3%	10.5%
80th	5.3%	0.0%	10.5%	5.3%	15.8%	15.8%	15.8%	0.0%	15.8%	15.8%
90th	14.3%	0.0%	9.5%	14.3%	14.3%	4.8%	9.5%	19.0%	9.5%	4.8%
100th	5.6%	11.1%	0.0%	11.1%	16.7%	5.6%	0.0%	5.6%	11.1%	33.3%

(m) Korea: Electrical Machinery 1999-2004

2004										
1999	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	16.0%	4.0%	12.0%	12.0%	4.0%	0.0%	8.0%	4.0%	16.0%	24.0%
20th	7.1%	25.0%	10.7%	14.3%	17.9%	7.1%	3.6%	3.6%	3.6%	7.1%
30th	13.3%	3.3%	10.0%	13.3%	23.3%	6.7%	10.0%	6.7%	6.7%	6.7%
40th	11.5%	3.8%	15.4%	19.2%	15.4%	7.7%	7.7%	15.4%	3.8%	0.0%
50th	16.7%	10.0%	16.7%	3.3%	16.7%	3.3%	16.7%	6.7%	6.7%	3.3%
60th	3.4%	10.3%	6.9%	6.9%	0.0%	24.1%	20.7%	10.3%	10.3%	6.9%
70th	9.1%	21.2%	12.1%	3.0%	12.1%	6.1%	15.2%	9.1%	9.1%	3.0%
80th	8.0%	8.0%	4.0%	12.0%	12.0%	20.0%	8.0%	8.0%	8.0%	12.0%
90th	6.5%	6.5%	9.7%	9.7%	6.5%	6.5%	9.7%	19.4%	6.5%	19.4%
100th	20.0%	16.7%	13.3%	6.7%	6.7%	3.3%	0.0%	10.0%	16.7%	6.7%

(n) China: Electrical Machinery 1999-2004

2004										
1999	10th	20th	30th	40th	50th	60th	70th	80th	90th	100th
10th	16.7%	33.3%	16.7%	0.0%	0.0%	0.0%	16.7%	0.0%	16.7%	0.0%
20th	50.0%	25.0%	0.0%	12.5%	0.0%	0.0%	0.0%	0.0%	0.0%	12.5%
30th	0.0%	33.3%	0.0%	16.7%	50.0%	0.0%	0.0%	0.0%	0.0%	0.0%
40th	12.5%	12.5%	0.0%	25.0%	25.0%	0.0%	12.5%	0.0%	12.5%	0.0%
50th	12.5%	25.0%	0.0%	25.0%	0.0%	25.0%	0.0%	12.5%	0.0%	0.0%
60th	0.0%	0.0%	22.2%	0.0%	11.1%	11.1%	0.0%	22.2%	11.1%	22.2%
70th	20.0%	0.0%	0.0%	20.0%	0.0%	20.0%	20.0%	0.0%	0.0%	20.0%
80th	25.0%	0.0%	12.5%	0.0%	0.0%	0.0%	37.5%	0.0%	0.0%	25.0%
90th	0.0%	0.0%	16.7%	0.0%	0.0%	0.0%	33.3%	0.0%	33.3%	16.7%
100th	0.0%	0.0%	14.3%	14.3%	0.0%	14.3%	0.0%	14.3%	14.3%	28.6%

4. Productivity Convergence Toward Frontier Firms

Our empirical analysis so far has shown that some industries in Korea achieved rapid TFP growth and that the ranking of firm TFP fluctuates more for Korean and Chinese firms than Japanese firms. On the other hand, industry-level TFP growth rates were very low and changes in firm TFP ranking very infrequent in Japanese industries. As a result, TFP levels in Korea have even surpassed Japanese TFP levels in some industries, such as stone, clay, and glass products, non-electrical machinery, electrical machinery, and transportation. Moreover, the dispersion of firm TFP has been widening in more industries in Japan than in Korea, although the magnitude of the TFP dispersion is much smaller for Japanese industries. These observations imply that technology diffusion across firms appear be stronger in Korea than in Japan and that convergence to the national frontier firms is more rapid for Korean firms than for Japanese firms.

In this section, following the methodology employed by Bartelsman, Haskel and Martin (2006), we estimate the speed of convergence to the productivity frontier. Like Bartelsman, Haskel and Martin (2006), we assume that changes in the knowledge capital of firm f , ΔA_f , originate from changes in the knowledge stock within the firm itself and from outside the firm, because knowledge inputs are potentially transferable and non-rival within and across firms. Therefore, we may write:

$$\Delta A_f = f(X_f, A_f, A_{-f}) \quad (4)$$

where X_f are the physical inputs into the idea process. Log linearizing this yields:

$$\Delta \ln A_f = \alpha_1 \ln X_f + (\alpha_2 - \alpha_3) \ln A_f + \alpha_3 \ln \left(\frac{A_{-f}}{A_f} \right) \quad (5)$$

where it is usual to impose $\alpha_2 = \alpha_3$, so the overall growth of A only depends on the relative levels of A_{-f} and A_f . As in Bartelsman, Haskel, and Martin (2006) and other studies in the convergence literature, we identify A_{-f} as the productivity level of the leading firm. In order to avoid measurement error problems, we take the average of the TFP of firms within the top-quartile of the TFP distribution by industry, year, and country. We call the productivity levels of the top-quartile firms the national frontier, A_N . The term $\ln(A_N/A_f)$ indicates the productivity gap between the national frontier and firm f . Therefore, we define the distance to the national frontier (DTF_N) as follows:

$$\begin{aligned} DTF_{Nf} &= \ln A_N - \ln A_f & \text{if } \ln A_f < \ln A_N \\ DTF_{Nf} &= 0, & \text{otherwise} \end{aligned} \quad (6)$$

Using firm-level TFP as a proxy for firms' knowledge capital, we can estimate the version of (5) given by:

$$\Delta \ln TFP_{ft} = \alpha + \beta DTF_{Nf,t-1} + \mu_f + \varepsilon_{ft} \quad (7)$$

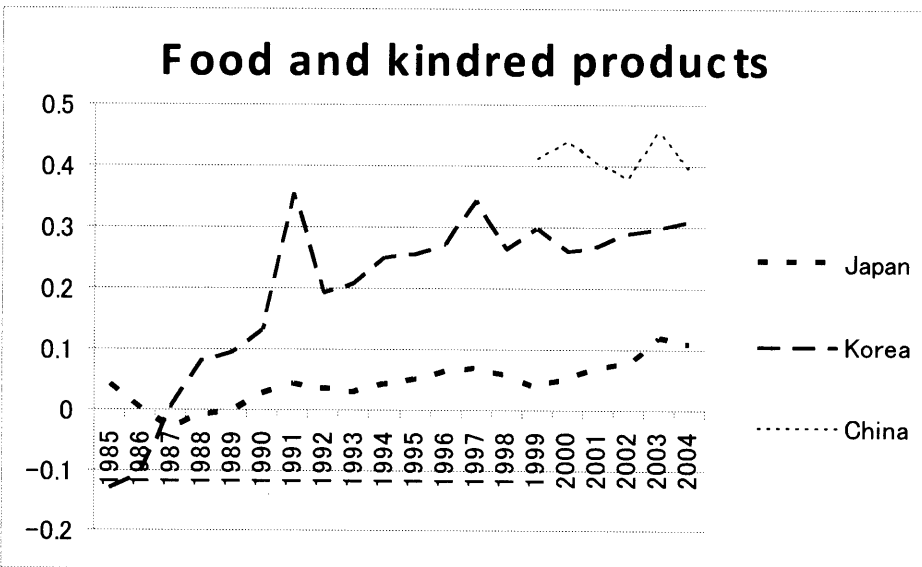
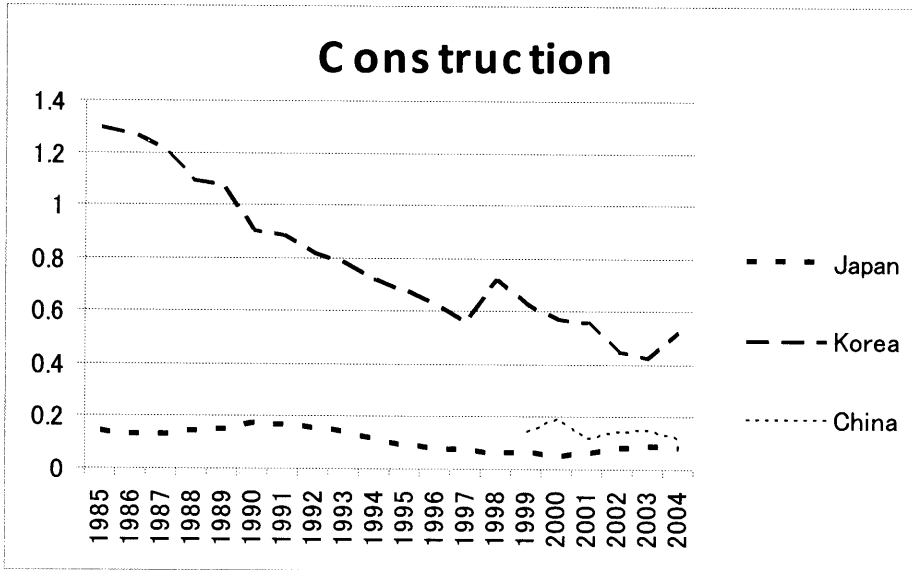
where α represents a constant as well as a dummy variable for time. β measures the pull from the frontier. If the marginal effect of technology spillovers or diffusion is larger for firms with a low TFP level,¹⁵ the value of β will be positive and we will see a catching-up of low-productivity firms to the national frontier. The firm-specific fixed effect, μ_f , captures the effect of firm actions and firm and industry characteristics on firm-level productivity growth. Although it would be desirable to include a better proxy for investment in knowledge creation such as R&D intensity, we do not do so because such data are not available for Korean and Chinese firms. In addition, we include the growth potential of the industry to control for industry characteristics. The growth potential is measured as the lagged average growth rate of the Japanese national frontier and the Korean national frontier.¹⁶ We estimate equation (7) using the fixed-effect panel regression method.

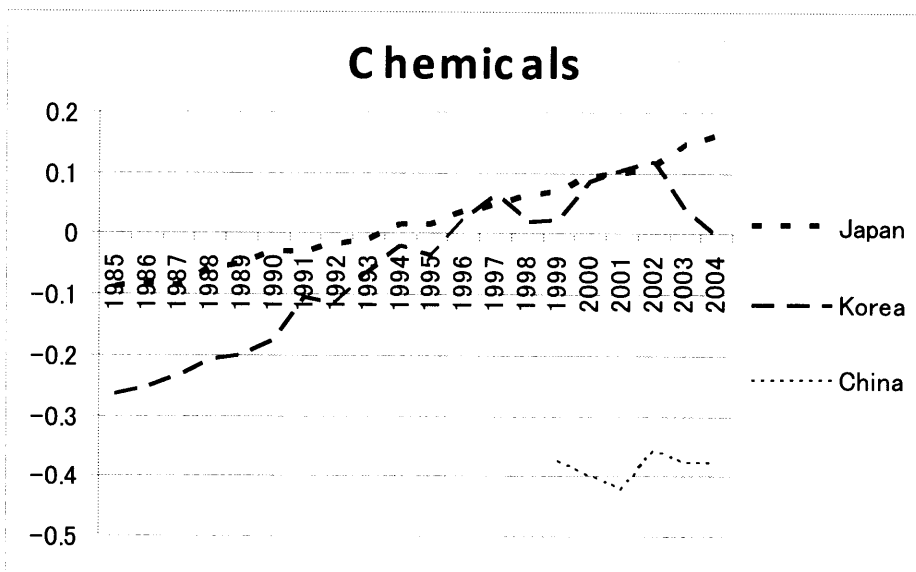
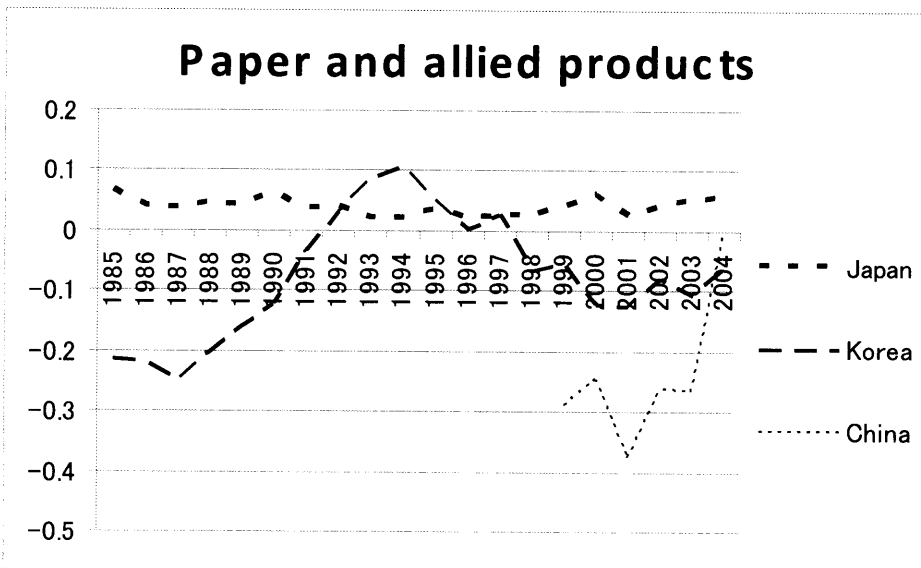
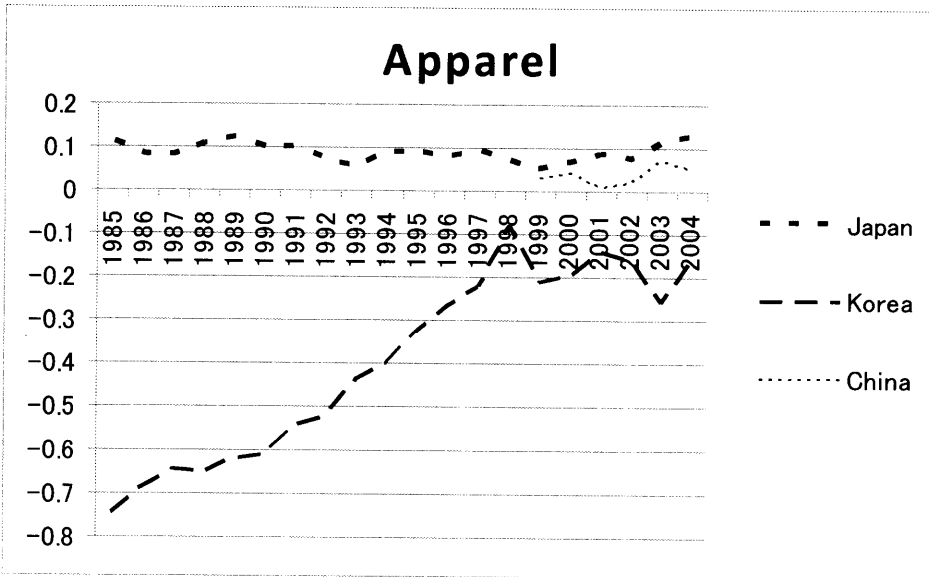
Before moving on to the estimation results, let us have a look at the trends in the national frontier TFP levels for the 12 major industries (Figure 4). Consistent with our analysis in the previous sections, the Japanese national frontier is the highest in the majority of industries. As Bartelsman, Haskel and Martin (2006) explain, firms with a knowledge gap vis-à-vis the national frontier firms can potentially learn from them while the national frontier firms presumably can also learn from the global frontier firms. Given the close economic relationships between Japan, Korea, and China, Korean and Chinese firms may have learned from Japanese frontier firms. Therefore, for Korean and Chinese firms, we also estimate the speed of convergence to the Japanese national frontier in the ten industries where the Japanese frontier is consistently higher than the Korean and Chinese frontiers, that is, textile mill products, apparel, paper and allied products, chemicals, primary metal products, electrical machinery, motor vehicles, rubber and miscellaneous plastics, miscellaneous manufacturing products, and trade.

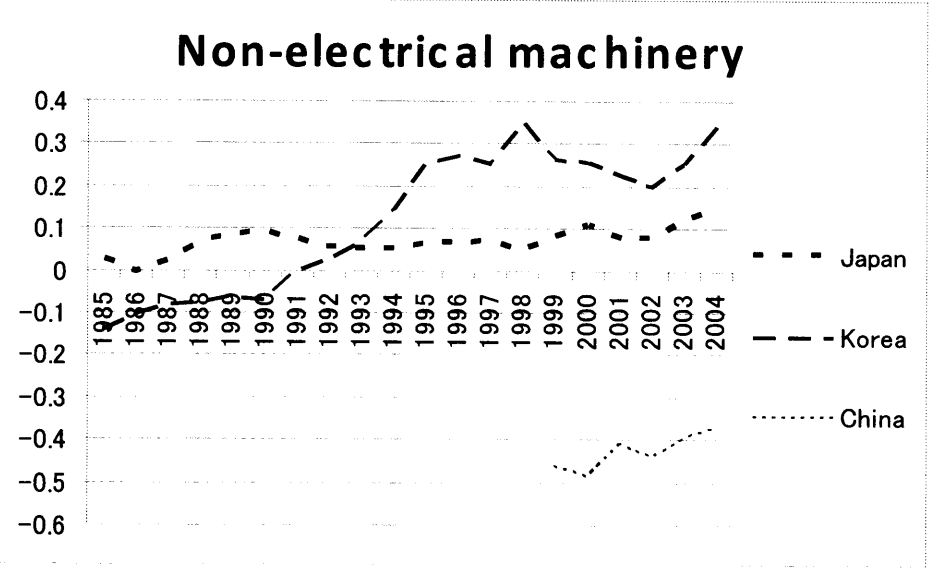
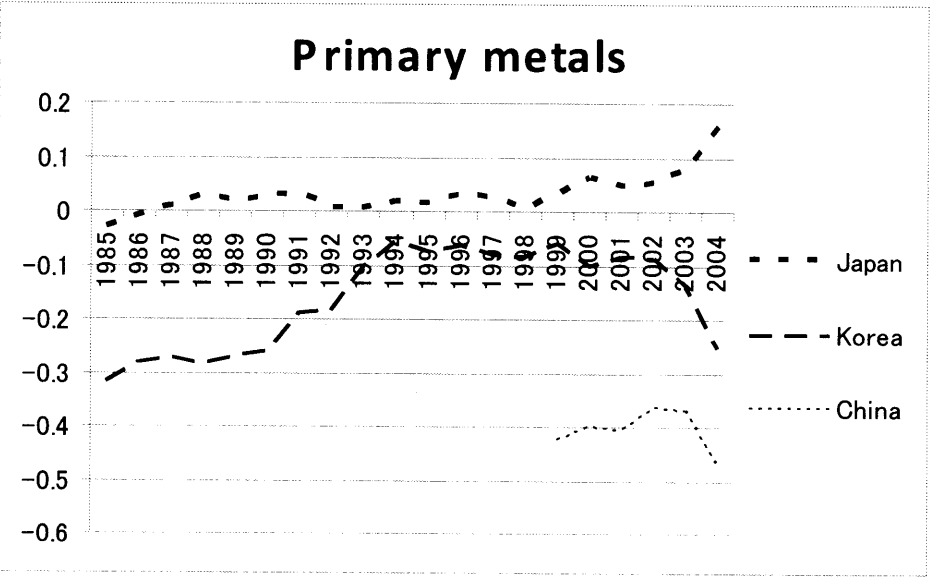
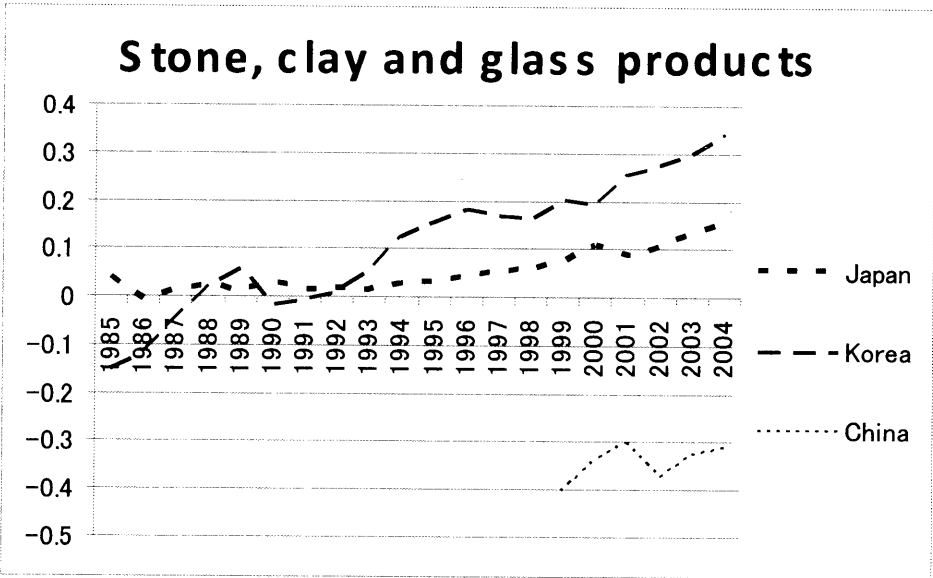
¹⁵ Whether low-productivity firms can benefit from the “advantages of backwardness” depends on patterns of consumption and on the existence of a threshold level of infrastructural development (Dowrick and Gemmell 1991, Hall and Jones 1999, Barro and Sala-i-Martin 2004).

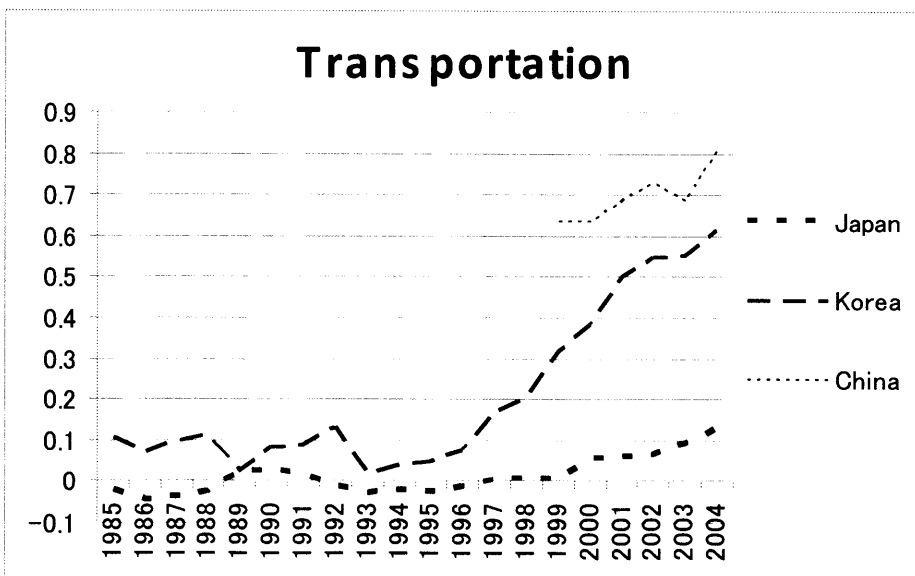
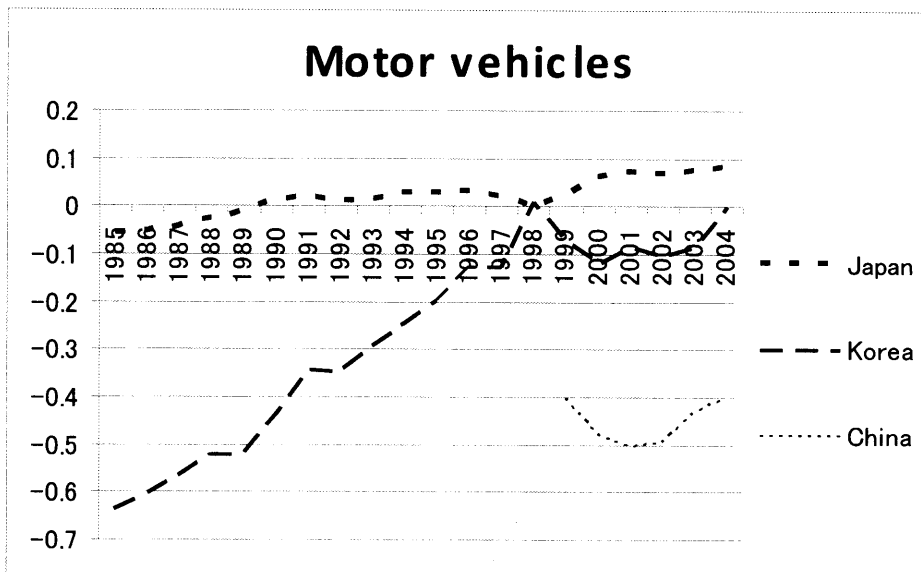
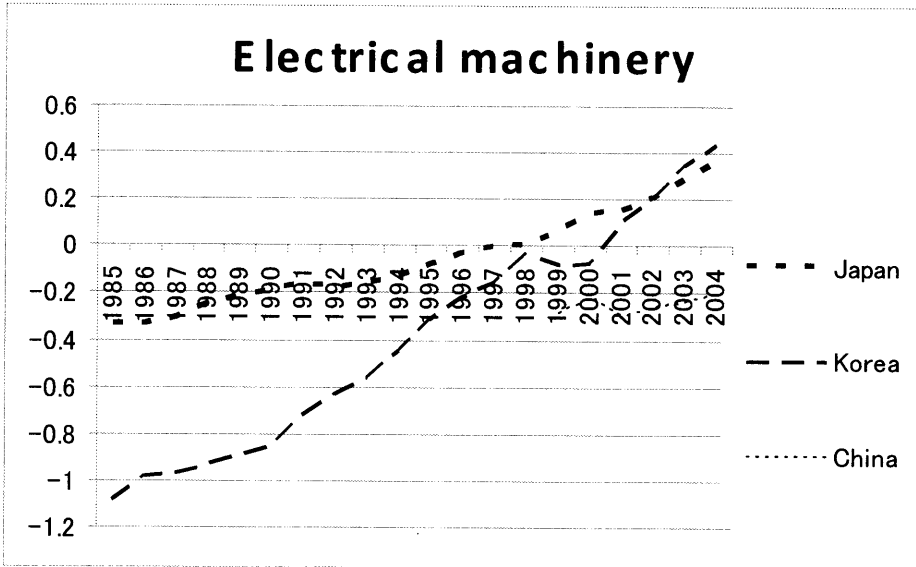
¹⁶ In some specifications, we use the lagged growth rate of the Japanese national frontier as a proxy for the growth potential of the industry.

Figure 3. Trends in TFP of national frontier firms









The estimation results are shown in Table 7. Column 1 shows a standard regression of TFP growth on the distance from the national frontier, using as control variables both the lagged growth rate of the industry TFP (the average growth rate of the Japanese and the Korean national frontiers, $dAF_{JK}(t-1)$) and year dummy variables. The marginal pull from the national frontier is 0.51.¹⁷ In order to examine whether the pull from the national frontier is different among countries, we interact the DTF_N measure with a dummy for each country (JP , KR , CH) separately. The result is shown in column 2 and indicates that the marginal impact of the national frontier is largest for Chinese firms, followed by that for Korean and then Japanese firms (the differences among these marginal effects are statistically significant).¹⁸ This result suggests that the convergence speed to the national frontier is the weakest for Japanese firms. Looking at the convergence speed to the Japanese frontier for Korean and Chinese firms (columns 5-7), we find that the marginal impact of the Japanese frontier on Korean TFP growth is much smaller than that of the Korean national frontier (0.08 and 0.45 respectively).¹⁹ However, in the case of Chinese firms, the marginal impact of the Japanese frontier is much larger than that of the Chinese national frontier. Although this may reflect the fact that the TFP growth of Chinese national frontier firms has stagnated in many industries (Figure 3), it may be possible that the knowledge spillovers among Korean firms are stronger than those among firms in China, where foreign-owned firms are playing a crucial role in technological upgrading.

¹⁷ The marginal pull from the national frontier estimated by Bartelsman, Haskel and Martin (2006) is around 0.2-0.3 for UK firms, although our results cannot be directly compared with theirs because of the different specification. Moreover, they use labor productivity as a productivity measure.

¹⁸ In order to check the robustness of this result, we estimated the same equations only for Japanese and Korean firms, because data on Chinese firms are available only from 1999. The results were very similar and robust.

¹⁹ The estimations reported in columns 5-7 include the lagged growth rate of the Japanese national frontier, $dAF_J(t-1)$, to control for the industry's growth potential.

Table 7: Fixed effect panel regression results

Dependent variable: TFP growth rate		(1)	(2)	(3)	(4)	(5)	(6)	(7)
		All	All	JPN & KOR	JPN & KOR	KOR & CHN	KOR	CHN
DTF _N		0.5132 (122.78) ***		0.4753 (114.68) ***			0.4527 (31.78) ***	0.1629 (2.34) **
DTF _N *JP			0.4092 (58.85) ***		0.4088 (62.36) ***			
DTF _N *KR			0.5181 (92.60) ***		0.5180 (98.20) ***	0.4466 (30.43) ***		
DTF _N *CH			0.8322 (65.51) ***			0.1413 (2.67) ***		
DTF _J							0.0783 (6.73) ***	0.8310 (11.56) ***
DTF _J *KR						0.0855 (7.15) ***		
DTF _J *CH						0.8660 (15.98) ***		
dAF _{JK} (t-1)		0.0029 (0.29)	0.0083 (0.83)	0.0043 (0.45)	0.0080 (0.83)			
dAF _J (t-1)						0.0359 (0.52)	-0.0065 (-0.09)	0.2204 (0.78)
No. of obs.		66423	66423	63757	63757	12220	10825	1395
No. of group:		6407	6407	5481	5481	1448	962	486
F statistics		828.7 ***	801.3 ***	731.6 ***	705.6 ***	180.0 ***	161.8 ***	97.3 ***

t-test for the difference in estimated coefficients for equation (2)

H0: DTF_N*JP vs. DTF_N*KR; significant at 1 percent level

H0: DTF_N*KR vs. DTF_N*CH; significant at 1 percent level

Notes:

All regressions include year dummies. DTF terms are all lagged one period.

t-values are in parentheses. Significance at the 1, 5, and 10 percent level is indicated by ***, **, and *, respectively.

Table 8 goes on to explore how much the distance-to-the-frontier (DTF) effects vary with the distance to the frontier. We assign quartile dummies for DTF measures (by country, year, and industry) and multiply them with each dummy separately, thus allowing the marginal effect of the different distances to vary according to quartile-location of distance. In columns 1-3, we show the results when only the distance to the national frontier is included. In the case of Korea, the DTF_N effect increases with the distance to the national frontier. On the other hand, the DTF_N effect is more or less flat for Japan and China, except for a slight increase for firms in the quartile farthest from the frontier. In columns 4 and 5, we report the result of adding the four Japanese frontier terms for the ten industries previously mentioned where the Japanese national frontier is consistently higher than that of Korea and China (see Figure 4 above). First, all the DTF_J coefficients are lower than the DTF_N coefficients in the case of Korea, while the Chinese results are exactly the opposite. Second, in the case of Korea, the DTF_J coefficients are declining with the distance to the Japanese frontier while the DTF_N coefficients are still increasing with the distance to the national frontier. In the case of China, although the DTF_J coefficients are somewhat decreasing with the distance, the difference between the coefficients for the top quartile and the bottom quartile is not statistically significant.

Table 8: Fixed effect panel regression results: Including interaction-terms

Dependent variable: TFP growth rate

	(1) Japan	(2) Korea	(3) China	(4) Korea	(5) China
DTF _N *q1	0.3967 (86.21) ***	0.5358 (65.47) ***	0.8341 (29.70) ***	0.5074 (24.23) ***	0.2301 (3.15) ***
DTF _N *q2	0.3757 (59.29) ***	0.4356 (31.18) ***	0.7823 (14.82) ***	0.3970 (13.72) ***	0.0547 (0.43)
DTF _N *q3	0.3723 (41.83) ***	0.4091 (19.45) ***	0.7952 (10.35) ***	0.4268 (11.54) ***	0.1304 (0.77)
DTF _N *q4	0.3801 (20.70) ***	0.3722 (7.65) ***	0.8244 (4.64) ***	0.3608 (5.69) ***	-0.4345 (-1.45)
DTF _J *q1				0.0424 (2.60) ***	0.8212 (11.29) ***
DTF _J *q2				0.0908 (6.02) ***	0.9079 (10.70) ***
DTF _J *q3				0.0939 (6.20) ***	0.8883 (9.99) ***
DTF _J *q4				0.0998 (6.13) ***	0.9810 (10.00) ***
dAF _{JK} (t-1)	-0.0209 (-2.73) ***	0.0673 (2.41) ***	0.0335 (0.25)	0.0879 (1.29)	0.5045 (2.30) **
No. of obs.	45624	18133	2666	10825	1395
No. of groups	3803	1678	926	962	486
F statistics	473.0 ***	225.9 ***	114.3 ***	125.6 ***	50.6 ***
t-test for the difference in estimated coefficients					
H0: DTF _N *q1 vs. DTF _N *q4					
	not significant	significant ***	not significant	significant **	significant **
H0: DTF _J *q1 vs. DTF _J *q4					
	n.a.	n.a.	n.a.	significant **	not significant

q1: the lowest 25%

q2: above 25% and below 50%

q3: above 50% and below 75%

q4: the highest 25%

Notes:

n.a. = not applicable.

All regressions include year dummies. DTF terms are all lagged one period.

t-values are in parentheses.

Significance at the 1, 5, and 10 percent level is indicated by ***, **, and *, respectively.

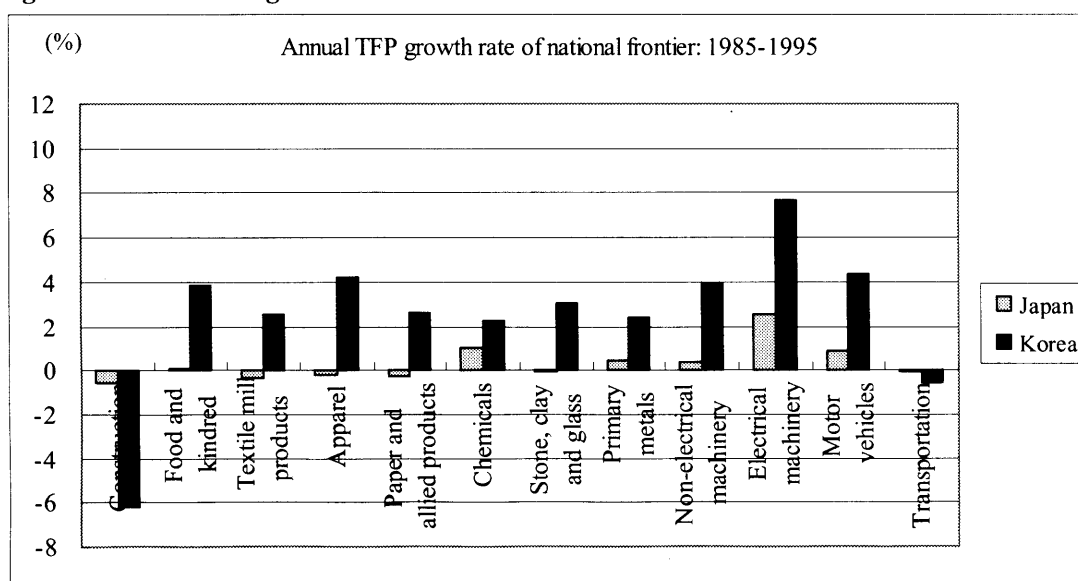
In sum, all these results point to the following interpretation. First, in the case of Japan, the pull from the national frontier is the weakest among the three countries, but the pull from the national frontier does not fall nor increase with technological distance. Second, in the case of Korea, the national frontier exerts a stronger pull on domestic firms than the Japanese frontier. Although the convergence rate is low for firms that are distant from the Japanese frontier, the

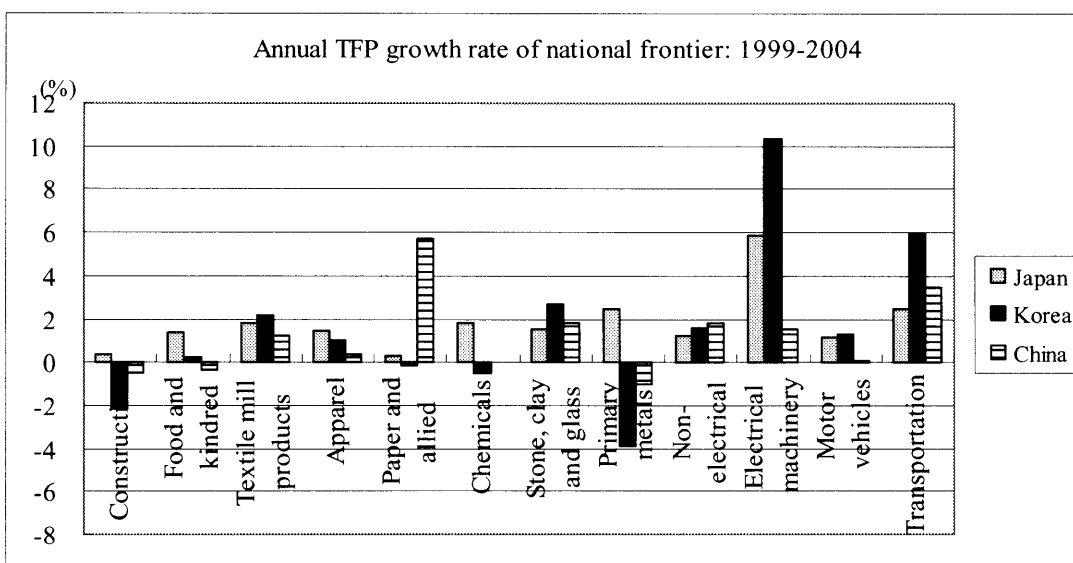
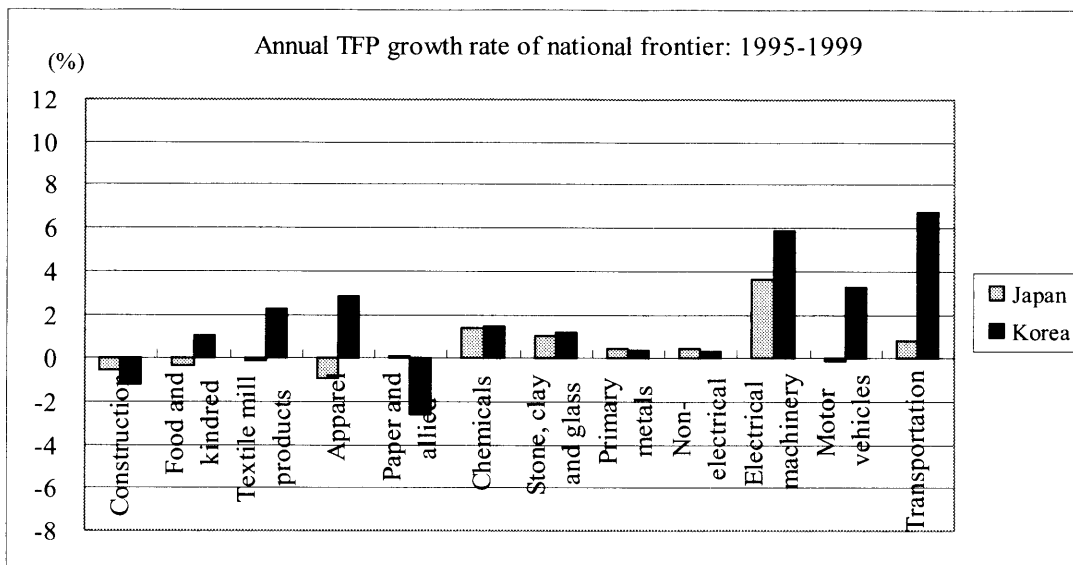
convergence rate is higher for firms that are distant from the national frontier. These results suggest that low-performing firms are rapidly catching up to the national frontier, while national frontier firms are also catching up to leading Japanese firms, though at a lower speed. Third, in the case of China, the pull from the national frontier is weaker than the pull from the Japanese frontier.

Thus, the strongest convergence towards the national frontier is found for Korean firms. This, in turn, suggests that if Korean national frontier firms were to reach the global frontier, we would expect that all Korean firms to catch up to the global frontier sooner or later. Therefore, the TFP growth of Korean national frontier firms is critical to Korea's productivity improvement and catch-up process. Figure 5 shows the annual TFP growth rate of national frontier firms in the three countries. Although in many industries the Korean TFP frontier had been advancing much more rapidly than the Japanese frontier up until 1999, Japanese frontier growth in many industries then outpaced Korea's from 1999 to 2004. While the Korean electrical machinery industry continues to raise its TFP at a high speed, TFP growth in many other industries has been stagnant in recent years. These figures suggest that the Korean electrical machinery industry will catch up to the global frontier in the near future, while other industries are far from achieving this result.

In Japan, the TFP growth rate of the national frontier is low for many industries, although it has been improving in recent years. The low growth rate of the national frontier and the weak pull from the national frontier may result in a further widening of the dispersion of productivity within an industry as well as the stagnation of industry-level productivity.

Figure 4: Annual TFP growth rate for national frontier firms





5. Concluding Remarks and Implications for Future Research

Using firm-level data, this paper explored differences in productivity growth and dispersion among Japanese, Korean, and Chinese listed firms. Moreover, we investigated the productivity convergence pattern for these countries.

We found the following. First, TFP has been growing faster in Korea than in Japan in some industries, such as textile mill products, apparel, stone, clay and glass products, non-electrical machinery, electrical machinery, motor vehicles, and transportation. In several industries, such as stone, clay and glass products, non-electrical machinery, electrical machinery, and transportation, the Korean TFP level even surpasses the Japanese TFP level.

Second, in most industries, the within-industry dispersion of productivity is smallest in Japan. Moreover, Japan has experienced a widening dispersion in more industries than Korea, although

in some industries, the speed of the widening of the dispersion is faster in Korea than in Japan.

Third, in Japan, TFP rankings within an industry are quite stable in many industries, while the rankings change frequently in Korea.

Fourth, the convergence analysis revealed that the pull from the national frontier was weaker in the case of Japan than that of Korea. In the case of Korea, lower-performing firms have been catching up to the national frontier at a faster speed than higher-performing firms, which provides evidence of strong convergence toward the national frontier. Moreover, the rapid TFP growth of the Korean national frontier in the electrical machinery industry suggests that this industry will catch up with the global frontier in the near future, while convergence toward the global frontier does not appear to be very strong in other industries.

According to our findings, the TFP distribution is very stable over time in Japan, which is conspicuously different from the situation in Korea and China. Moreover, the speed of TFP convergence is the slowest in Japan. These differences may be attributable to differences in country- or industry-level technological capabilities, industry organization, market conditions, and institutional infrastructure, or in micro-level R&D activities and managerial ability.²⁰ Although we did not analyze in detail the effect of these macro- and micro-level characteristics due to a lack of data, particularly for Korean and Chinese firms, this is an issue to be further scrutinized if the necessary data become available. Furthermore, firm-level or industry-level analyses including a greater number of both developed and developing countries should provide us with an understanding of the relationship between productivity dynamics and country-specific factors.

Moreover, our finding of a positive catching-up effect towards the national frontier in all three countries may seem contradictory to another of our findings, namely that within-industry TFP dispersion has been widening in many industries. A possible explanation is that our convergence analysis only takes account of “passive” technology diffusion or, in other words, “autonomous” productivity convergence (Nishimura, Nakajima and Kiyota, 2005). Although we partly controlled for firm-specific characteristics using the fixed-effect panel estimation methodology, we did not fully take account of “active” technology diffusion which is brought about by firms’ R&D activities for the purpose of adopting new technology. In addition, as many recent micro-level studies show, exposure to international competition possibly affects firms’ productivity.²¹ We would like to further scrutinize the issue related to firm-level convergence and within-industry dispersion of productivity in the future. Unfortunately, we were unable to do so

²⁰ Previous studies on within-country convergence show that the convergence speed is influenced by firms’ own R&D activities (Nishimura, Nakajima and Kiyota, 2005) and the presence of foreign-owned firms (Griffith, Redding and Simpson, 2002).

²¹ See Fukao and Kwon (2006) for the case of Japan. Also refer to Bartelsman and Doms (2000) for a comprehensive survey.

in this study due to the unavailability of firm-level data on the R&D and international activities of Korean and Chinese firms.

The mechanism of productivity convergence to frontier firms within a country and across countries is an issue that deserves further attention and more rigorous empirical analysis. Although the compilation of international micro data for East Asian countries is not an easy task, the development of internationally comparable measures based on micro data could shed more light on the growth mechanisms underlying the so-called “East Asian economic miracle,” as well as the determinants and consequence of the heterogeneity of firms.

Moreover, we need to improve the quality and coverage of our micro data as well as currency conversion factors, human capital, price deflators, etc., in order to measure industry- or firm-level productivity more accurately. It is also important to further develop the methodology used for the measurement of internationally-comparable TFP. In this study, we were not able to analyze the productivity of global frontier firms because comprehensive firm-level data were not available for the United States and for European countries. A comparison of the performance and/or competition between Asian frontier firms and frontier firms in developed countries from other regions would be another interesting research topic which deserves further investigation.

Appendix : Measurement Issues and Data Sources

This appendix provides a brief discussion of measurement issues and data sources relevant to the analysis in this paper. For details on the calculation of internationally comparable TFP, see Fukao et al. (2007).

TFP calculation

We calculate each firm's TFP by following the method of Good, Nadiri and Sickles (1997), taking the year 1999 as the base period:

$$\begin{aligned} \ln TFP_{f,t} = & (\ln Q_{f,t} - \overline{\ln Q_t}) - \sum_{i=1}^n \frac{1}{2} (S_{f,i,t} + \overline{S_{i,t}}) (\ln X_{f,i,t} - \overline{\ln X_{i,t}}) \\ & + \sum_{s=1}^t (\overline{\ln Q_s} - \overline{\ln Q_{s-1}}) - \sum_{s=1}^t \sum_{i=1}^n \frac{1}{2} (\overline{S_{i,s}} + \overline{S_{i,s-1}}) (\overline{\ln X_{i,s}} - \overline{\ln X_{i,s-1}}) \end{aligned} \quad (A1)$$

where $Q_{f,t}$, $S_{f,i,t}$, and $X_{f,i,t}$ 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. This index measures the productivity level of firm f in year t in a certain industry in comparison with the productivity level of a hypothetical representative firm in the base year in that industry. The hypothetical firm has input cost shares that equal the arithmetic mean of costs over all firms and has output and input levels that equal the arithmetic mean of the log of the output and the inputs over all firms in that industry, respectively.

However, in order to conduct an international comparison of TFP levels, we need to know the absolute gap in the productivity levels of hypothetical representative firms in the base year in an industry across countries. Therefore, we modify equation (A1) as follows:

$$\begin{aligned} \ln TFP_{f,j,c,t} = & (\ln Q_{f,j,c,t} - \overline{\ln Q_{j,c,t}}) - \sum_{i=1}^n \frac{1}{2} (S_{f,j,c,i,t} + \overline{S_{j,c,i,t}}) (\ln X_{f,j,c,i,t} - \overline{\ln X_{j,c,i,t}}) \\ & + \sum_{s=1}^t (\overline{\ln Q_{j,c,s}} - \overline{\ln Q_{j,c,s-1}}) - \sum_{s=1}^t \sum_{i=1}^n \frac{1}{2} (\overline{S_{j,c,i,s}} + \overline{S_{j,c,i,s-1}}) (\overline{\ln X_{j,c,i,s}} - \overline{\ln X_{j,c,i,s-1}}) \\ & + \ln \mu_{c,j,Japan,1999} \end{aligned} \quad (A2)$$

Here, $\ln TFP_{f,j,c,t}$ is the natural logarithm of the TFP of firm f in industry j and country c at time t ; $\ln Q_{f,j,c,t}$ is the natural logarithm of the real output of firm f in industry j and country c at time t ; $\ln X_{f,j,c,i,t}$ is the natural logarithm of the real input of production factor i of firm f in industry j and country c at time t ; and $S_{f,j,c,i,t}$ is the cost share of production factor i of firm f in industry j and country c at time t .

Variables with an upper bar denote the geometric average of all firms in industry j in country c at

time t . The last term of equation (A2) indicates the natural logarithm of the TFP of industry j in country c in 1999 relative to the TFP of industry j in Japan. Therefore, this term represents the absolute TFP gap between the representative firm of industry j in country c and that of Japan in 1999. We calculate this absolute gap as described in the next subsection.

International Comparison of the TFP Level in the Benchmark Year

We obtained the relative TFP at the industry level in 1999 in accordance with the method adopted by Schreyer (2005). The relative TFP for industry j of two countries, A and B , $\ln \mu_{j,t}^{AB}$, is defined as follows:

$$\ln \mu_{j,t}^{AB} = \ln \theta_{Q,j,t}^{AB} - \left[\bar{v}_{K,j,t}^{AB} \ln \theta_{K,j,t}^{AB} + \bar{v}_{L,j,t}^{AB} \ln \theta_{L,j,t}^{AB} + \bar{v}_{M,j,t}^{AB} \ln \theta_{M,j,t}^{AB} \right] \quad (A3)$$

On the right-hand side of equation (A3), from left to right, are the relative output, relative capital input, relative labor input, and relative intermediate input of countries A and B , with \bar{v} on the right-hand side, also from left to right, showing the average cost shares of capital, labor, and intermediate input for countries A and B .

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 obtained in the following manner:

- (1) Relative output was obtained using the following formula:

$$\ln \theta_{Q,j,t}^{AB} = \left(\overline{\ln Q_{j,t}^A} - \overline{\ln Q_{j,t}^B} \right) - \ln q_{Q,j,t}^{AB}$$

where $\overline{\ln Q_{j,t}^c}$ is the geometric average of the output of all firms in industry j in country c at time t , while $\ln q_{Q,j,t}^{AB}$ indicates the relative output price between countries A and B in industry j at time t .

- (2) Relative capital input was obtained using:

$$\ln \theta_{K,j,t}^{AB} = \sum_s^N \bar{w}_{j,s,t}^{AB} \left[\left(\overline{\ln K_{j,s,t}^A} - \overline{\ln K_{j,s,t}^B} \right) - \ln q_{K,j,s,t}^{AB} \right]$$

where $\overline{\ln K_{j,s,t}^c}$ is the geometric average of the capital stock of all firms for capital good s in industry j in country c at time t , while $\ln q_{K,j,s,t}^{AB}$ indicates the relative price in countries A and B of capital good s for industry j at time t . Further, $\bar{w}_{j,s,t}^{AB}$ shows the average cost share of capital good s in industry j at time t in countries A and B .

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

$$\ln \theta_{L,j,t}^{AB} = \overline{\ln LH_{j,t}^A} - \overline{\ln LH_{j,t}^B}$$

where $\overline{\ln LH_{j,t}^c}$ is the geometric average of the labor input (work hours) of all firms in industry j in country c at time t .

(4) The relative intermediate input was calculated using:

$$\ln \theta_{M,j,t}^{AB} = \left(\overline{\ln M_{j,t}^A} - \overline{\ln M_{j,t}^B} \right) - \ln q_{M,j,t}^{AB}$$

where $\overline{\ln M_{j,t}^c}$ is the geometric average of the intermediate input of all firms in industry j of country c at time t , while $\ln q_{M,j,t}^{AB}$ corresponds to the relative intermediate input price in countries A and B in industry j at time t .

We need to convert output and inputs by firms in each country to a common currency with a currency conversion factor which takes account of cross country differences in relative price levels. We construct PPP indexes by industry utilizing the PPP constructed by the ICPA (International Comparison of Productivity Among Asian Countries) project at RIETI (see Motohashi 2005 and <http://www.rieti.go.jp/jp/database/data/icpa-description.pdf>).

Data Sources

1. Japan

To measure the TFP level of listed firms in Japan, we use the firm-level database compiled by the Development Bank of Japan (DBJ).

Output

For output, we use sales after adjusting for inventory. For the wholesale and retail industry, purchases of merchandise are subtracted from sales. The price indexes for output and intermediate input are taken from the Japan Industry Productivity Database 2006 (JIP2006). The JIP2006 database provides deflators up to 2002. We extended these up to 2004 using SNA deflators.

Inputs

To calculate TFP, we take account of three types of inputs: capital, labor, and intermediate input. For capital input, we use capital stock, not capital service. It has been shown that, under certain assumptions, capital service is proportional to real capital stock. For labor input, we use the number of employees of each firm multiplied by the industry-average hours worked.

Prices of Capital Goods

The six asset components of capital goods are:

- (1) nonresidential buildings,
- (2) structures,
- (3) machinery,
- (4) transportation equipment,
- (5) instruments and tools, and
- (6) land.

For (1) and (2), the price index for construction materials of the Corporate Goods Price Index (CGPI) compiled by the Bank of Japan is used. The price index for machinery (3) is calculated as the weighted average of three CGPI components: general machinery & equipment, electrical machinery & equipment, and precision instruments. We use the capital formation matrixes for 1985, 1990, 1995, and 2000 rearranged by RIETI by industry as fixed weights. A similar procedure is used to construct the price index for instruments and tools, i.e., it is calculated as the weighted average of five CGPI components: metal products, general machinery & equipment, electrical machinery & equipment, precision instruments, and other manufacturing industry products. The capital formation matrixes are used as fixed weights here too. The transportation equipment component of the CGPI is adopted as the price index for transportation equipment (4). For the price of land (6), we use the index of urban land prices compiled by the Japan Real Estate Research Institute. The index for commercial areas is adopted for non-manufacturing firms, whereas that for industrial areas is adopted for manufacturing firms.

Nominal Investment Amount for Capital Goods

To obtain capital stocks using the perpetual inventory method, we need the nominal investment amount for each capital good. The following notations are used for calculating nominal investment:

- | | |
|---------|---|
| KGB_t | book value of gross capital stock at the end of period t |
| KNB_t | book value of net capital stock at the end of period t |
| AD_t | book value of accumulated depreciation at the end of period t |
| DEP_t | accounting depreciation during period t |

The definition of nominal investment is:

$$NOMI_t = KNB_t - KNB_{t-1} + DEP_t \quad (A3)$$

Since DEP_t is not available until 1977, $(AD_t - AD_{t-1})$ was used as a weight to distribute total

depreciation between assets (1) to (5) listed above.

Capital Stock

Real capital stock using the perpetual inventory method is calculated as follows:

$$K_t = (1 - \delta)K_{t-1} + \frac{NOMI_t}{PK_t} \quad (A4)$$

where PK_t is the price index for the capital asset. The initial point for the perpetual inventory method is chosen to be 1970 because that is the first year for which depreciation data are available.

For land, this method needs to be adjusted a little. We do not know when the land which was sold during this period was acquired, so that it is not clear how to apply the price index for land to the land value sold during the period. We therefore assume the “last-in-first-out” principle for land. That is, when firms sell land, it is assumed that they sell the land which was acquired last.

Capital Cost

The cost of capital is obtained by multiplying capital stock by the capital service price and applying the following formula:

$$c_k(t) = \frac{1 - z(t)}{1 - u(t)} P_{kj}(t) \{ \lambda(t)r(t) + (1 - u(t))(1 - \lambda(t))i(t) + \delta_j - \left(\frac{\dot{P}_{kj}(t)}{P_{kj}(t)} \right) \}$$

where P_{kj} stand for the price of investment good j , u is the effective corporate tax rate, r is the long-term government bond rate, i is the long-term lending rate, λ is the own-capital ratio, and δ the depreciation rate. Meanwhile, z is the expected present value of tax saving due to depreciation allowances on one unit of investment, which was obtained based on the formula below:

$$z(t) = (u(t) \cdot \delta_j) / [\{ \lambda(t)r(t) + (1 - u(t))(1 - \lambda(t))i(t) \} + \delta_j]$$

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

2. Korea

To measure the TFP level of listed firms in Korea, we use the firm-level database provided by the

Korea Information Service (KIS).

Output and Material Deflators

- Output: the Producer Price Index (PPI) published by the Bank of Korea (BOK)
- Material:
 - 1984-2002: Pyo, Rhee and Ha (2006)
 - 2003-2005: intermediate goods and material deflator published by BOK

Labor Input

We use the number of employees of each firm multiplied by the industry-average hours worked. The industry-average hours worked are taken from the *Monthly Labor Survey*, Ministry of Labor.

Data for Capital Cost

- Interest rates: BOK
- Corporate tax rate: Kim, Park and Ahn (2003)
- Own capital ratio: KIS, financial statements
- Deflators: BOK
 - Land: land price index
 - Buildings and structures: intermediate goods and material deflator for construction
 - Machinery, tools, and vehicles: total fixed asset formation deflator
- Depreciation rates: Pyo (2002)

Output and Material Inputs

For output, inventory adjusted sales are used. Material input is calculated as COST OF SALES + SELLING & GENERAL ADMIN. EXPENSES – DEPRECIATION – LABOR COSTS. The price indexes for output and intermediate input are taken from Pyo, Rhee and Ha (2006).

Prices of Capital Goods

The six asset components of capital goods are:

- (1) nonresidential buildings,
- (2) structures,
- (3) machinery,
- (4) transportation equipment,
- (5) instruments and tools, and furniture
- (6) land.

For (1) and (2), the price index of materials and intermediate goods for construction published by the BOK are used. For (3), (4), and (5), the fixed capital formation deflator published by the BOK is used. For land, the index of Seoul land prices compiled by the BOK is used.

For each capital input, real capital stock is calculated as follows using the perpetual inventory method:

$$K_t = (1 - \delta)K_{t-1} + \frac{NOMI_t}{PK_t}$$

where PK_t is the price index for the capital asset. The initial point for the perpetual inventory method is 1980. The depreciation rate δ is taken from Pyo (2002). The depreciation rates for the asset components are: (1) 1.8%; (2) 3.4%; (3) 11.3%; (4) 20.5%; and (5) 11.3%.²²

$NOMI_t$ is nominal investment in year t and is taken from the financial statements in the KIS firm-level database.

Capital Cost

To calculate the cost share of each input, the capital cost of each capital input c_k is calculated as follows:

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

where z is the expected present value of tax saving due to depreciation allowances on one dollar of investment in capital goods, u is the effective corporate tax rate, λ is the own-capital ratio, r is the long-term government bond rate, i is the long-term corporate bond rate, δ is the depreciation rate, and p_k is the price index for each type of capital.

z is calculated as follows:

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

Following Hayashi and Inoue (1991), the effective corporate tax rate u_t is calculated as follows:

$$u_t = \frac{(t_t + v_t)(1 + r_t)}{(1 + r_t + v_t)}$$

where t_t is the corporate tax rate, v_t is the enterprise tax rate, and r_t is the short-term interest rate.

Nominal capital cost is calculated by multiplying c_k by the real capital stock K_t . Labor costs and material costs can be obtained directly from the KIS firm-level database.

3. China

²² For comparison, Hayashi and Inoue (1991) use depreciation rates of (1) 4.7%, (2) 5.64%, (3) 9.489%, (4) 14.70%, and (5) 8.838%.

To measure the TFP level of listed firms in China, we use the firm-level China Stock Market Database (CSMAR) provided by Guo Tai An Group.

Output and Material Deflators

Output: The price indexes for output for manufacturing industries are taken from the National Bureau of Statistics (NBS). The price indexes for output for agriculture and services are taken from the *China Statistical Yearbook*.

Materials: The price indexes for materials are estimated using the original price data from the NBS and the *Input-Output Table 2002*.

Labor Hours

We use the numbers of employees of each firm multiplied by industry-average hours worked estimated using the *Population Survey 1995* and Yang (2003).

Capital Cost and Capital Stock

Capital cost is calculated using the same formulas we used for Korea. Firm-level capital stock is calculated using the perpetual inventory method in the same fashion as for Japan and Korea. The data used to calculate capital cost and capital stock and the data sources are as follows:

- Interest rate: from The People's Bank of China (PBC);
- Corporate tax rate: calculated from the CSMAR database;
- Deflator: estimated using the original price data from the NBS and the *Input-Output Table 2002*. We used the average price of capital goods, including machinery, tools, vehicles, and buildings and structures.
- Depreciation rate: taken from Fraumeni (1997).

References

- Baily, Martin, Charles Hulten, and David Campbell (1992) "Productivity Dynamics in Manufacturing," *Brookings Papers on Economic Activity: Microeconomics*, 187-267.
- Barro, Robert J. and Xavier Sala-i-Martin (2004) *Economic Growth*, 2nd Edition, Cambridge, MA: MIT Press.
- Bartelsman, Eric and Mark Doms (2000) "Understanding Productivity: Lessons from Longitudinal Micro-Data," *Journal of Economic Literature*, 38(3): 569-594.
- Bartelsman, Eric, John Haltiwanger, and Stefano Scarpetta (2004) "Microeconomic Evidence of Creative Destruction in Industrial and Developing Countries," *IZA DP 1374*, Bonn: Institute for the Study of Labor.
- Bartelsman, Eric, John Haltiwanger, and Stefano Scarpetta (2005) "Measuring and Analyzing Cross-country Differences in Firm Dynamics," Paper presented at the 2nd Consortium Meeting of EU KLEMS, June 9-11, 2005, Helsinki.
- Bartelsman, Eric, Jonathan Haskel, and Ralf Martin (2006) "Distance to Which Frontier? Evidence on Productivity Convergence from International Firm-Level Data," Paper presented at the 2006 International Comparative Analysis of Enterprise (Micro) Data Conference, September 18-19, 2006, Chicago,.
- Bartelsman, Eric, Stefano Scarpetta, and Fabiano Schivardi (2003) "Comparative Analysis of Firm Demographics and Survival: Macro-Level Evidence for the OECD Countries," *OECD Economic Department Working Papers 348*, Paris: Organisation for Economic Co-operation and Development.
- Dowrick, Steve and Norman Gemmill (1991) "Industrialisation, Catching Up and Economic Growth: A Comparative Study Across the World's Capitalist Economies," *Economic Journal* 101(405): 263-275.
- Fraumeni, Barbara M. (1997) "The Measurement of Depreciation in the U.S. National Income and Product Accounts," *Survey of Current Business*, July: 7-23.
- Fukao, Kyoji, Tomohiko Inui, Shigesaburo Kabe, and Deqiang Liu (2007) "International Comparison of TFP Levels in Japanese, Korean and Chinese Listed Firms," forthcoming in *Seoul Journal of Economics*.
- Fukao, Kyoji and Hyeog Ug Kwon (2006) "Why Did Japan's TFP Growth Slow Down in the Lost Decade? An Empirical Analysis Based on Firm-Level Data of Manufacturing Firms," *Japanese Economic Review* 57(2): 195-228.
- Good, David H., M. Ishaq Nadiri, and Robin C. Sickles (1997) "Index Number and Factor Demand Approaches to the Estimation of Productivity," in M. Hashem Pesaran and Peter Schmidt (eds), *Handbook of Applied Econometrics: Microeconomics*, vol. II, Oxford:

Blackwell.

- Griffith, Rachel, Stephen Redding, and Helen Simpson (2002) "Productivity Convergence and Foreign Ownership at the Establishment Level, *CEPR Discussion Paper 3765*, London: Centre for Economic Policy Research.
- Hayashi, Fumio and Tohru Inoue (1991) "The Relation between Firm Growth and Q with Multiple Capital Goods: Theory and Evidence from Panel Data on Japanese Firms," *Econometrica*, 59(3): 731-753.
- Hall, Robert E. and Charles I. Jones (1999) "Why Do Some Countries Produce So Much More Output per Worker than Others?," *Quarterly Journal of Economics*, 114(1): 83-116.
- Kim, Jin Su, Hyung Soo Park and Jongseok Ahn (2003) "Corporate Tax Rate Policy: Recent Trends and Its Economic Effects," Report by the Korea Institute of Public Finance (in Korean).
- Kim, Young Gak, Hyeog Ug Kwon and Kyoji Fukao (2007) "Kigyo Jigyosho no Sannyu Taishutsu to Sangyo Reberu no Seisansei [Entry and Exit of Firms or Plants and Industry-Level Productivity]," *RIETI Discussion Paper Series 07-J-022*, Research Institute of Economy, Trade and Industry.
- Kojima, Kiyoshi (2003) *Gankogata Keizai Hatten-ron 1: Nihon Keizai, Ajia Keizai, Sekai Keizai* [The Flying-Geese Pattern of Economic Development, Volume 1: The Japanese Economy, the Asian Economy, and the World Economy], Tokyo: Bunshindo.
- Motohashi, Kazuyuki (2005) "Assessing Japan's Industrial Competitiveness by International Productivity Level Comparison with China, Korea, Taiwan, and United States," Paper presented at the International Conference on Productivity and Efficiency, Academia Sinica Economic Institute, June 20, 2005, Taipei.
- Nishimura, Kiyohiko G., Takanobu Nakajima, and Kozo Kiyota (2005) "Innovation versus Diffusion: Determinants of Productivity Growth Among Japanese Firms," *CIRJE Discussion Paper Series CIRJE-F-350*, Center for International Research on the Japanese Economy, University of Tokyo.
- Olley, Steve G. and Ariel Pakes (1996) "The Dynamics of Productivity in the Telecommunications Equipment Industry," *Econometrica*, 64(6): 1263-1297.
- Pyo, Hak K. (2002) "Estimates of Capital Stocks by Industries and Types of Assets in Korea (1953-2000)," *mimeograph*, Institute of Economic Research, Seoul National University.
- Pyo, Hak K., Keun-Hee Rhee and Bongchan Ha (2006) "Growth Accounting and Productivity Analysis by 33 Industrial Sectors in Korea (1984-2002)." *Hi-Stat Discussion Paper Series No. 171*, Institute of Economic Research, Hitotsubashi University.
- Shreyer, Paul (2005) "International Comparison of Levels of Capital Input and Productivity,"

Paper presented at the OECD/Ivie/BBVA Workshop on Productivity Measurement, 17-19 October 2005, Madrid.

Yang, Jianchun (2003) "China Working Time Statistics," Paper presented at the fifth Paris Group Meeting, September 4-5, 2003, London.

Appendix Table 1. TFP growth rates and the gap between the weighted average and the unweighted average TFP levels

Manufacturing Industry		TFP growth rate			Difference in the gap*		
		Japan	Korea	China	Japan	Korea	China
6 Food and kindred products	1985-1995	-0.4%	37.8%	n.a.	0.000	0.024	n.a.
	1995-1999	-0.9%	-5.6%	n.a.	0.007	0.001	n.a.
	1999-2004	6.0%	9.5%	-1.5%	0.006	0.044	0.071
7 Textile mill products	1985-1995	-6.0%	30.4%	n.a.	0.010	0.032	n.a.
	1995-1999	-0.2%	7.9%	n.a.	-0.002	0.016	n.a.
	1999-2004	7.8%	8.2%	0.8%	-0.004	0.027	0.016
8 Apparel	1985-1995	-5.7%	42.2%	n.a.	-0.003	0.000	n.a.
	1995-1999	-2.5%	1.5%	n.a.	-0.013	-0.005	n.a.
	1999-2004	5.0%	13.2%	4.0%	-0.011	0.013	-0.120
9 Lumber and wood	1985-1995	-5.6%	-1.5%	n.a.	-0.026	-0.051	n.a.
	1995-1999	-4.0%	4.1%	n.a.	-0.007	0.038	n.a.
	1999-2004	1.3%	15.7%	n.a.	0.011	0.022	n.a.
10 Furniture and fixtures	1985-1995	-6.3%	30.5%	n.a.	-0.009	0.027	n.a.
	1995-1999	-1.9%	5.4%	n.a.	0.003	0.012	n.a.
	1999-2004	2.5%	-1.0%	-5.8%	0.000	-0.015	0.136
11 Paper and allied products	1985-1995	-2.2%	21.6%	n.a.	-0.011	-0.053	n.a.
	1995-1999	-1.7%	-15.6%	n.a.	-0.010	-0.023	n.a.
	1999-2004	2.9%	7.9%	7.3%	0.006	0.035	0.058
12 Printing, publishing and allied products	1985-1995	-5.9%	69.9%	n.a.	-0.006	0.082	n.a.
	1995-1999	-4.8%	-3.0%	n.a.	-0.008	-0.085	n.a.
	1999-2004	0.3%	-11.1%	-2.9%	-0.035	0.127	0.150
13 Chemicals	1985-1995	8.1%	24.4%	n.a.	0.004	0.008	n.a.
	1995-1999	6.3%	7.9%	n.a.	0.010	0.010	n.a.
	1999-2004	9.7%	-4.8%	3.0%	0.030	0.001	0.010
14 Petroleum and coal products	1985-1995	-34.6%	84.6%	n.a.	-0.005	-0.009	n.a.
	1995-1999	0.3%	-55.7%	n.a.	0.008	-0.048	n.a.
	1999-2004	10.5%	-24.4%	12.7%	0.039	0.080	0.068
15 Leather	1985-1995	-19.3%	8.7%	n.a.	0.023	0.062	n.a.
	1995-1999	-1.4%	-6.5%	n.a.	-0.013	0.036	n.a.
	1999-2004	8.0%	-6.5%	0.0%	-0.003	-0.003	0.045
16 Stone, clay and glass products	1985-1995	-2.0%	30.3%	n.a.	-0.013	-0.050	n.a.
	1995-1999	3.0%	1.1%	n.a.	0.010	0.006	n.a.
	1999-2004	10.4%	17.4%	18.5%	0.032	0.041	0.062
17 Primary metals	1985-1995	7.0%	27.8%	n.a.	0.033	0.016	n.a.
	1995-1999	2.7%	-4.3%	n.a.	0.015	-0.022	n.a.
	1999-2004	7.7%	-14.3%	-1.4%	0.006	0.031	0.039
18 Fabricated metals	1985-1995	-2.1%	57.4%	n.a.	-0.029	0.140	n.a.
	1995-1999	0.3%	-12.0%	n.a.	0.000	0.003	n.a.
	1999-2004	3.1%	-7.5%	12.6%	0.015	0.010	0.271
19 Non-electrical machinery	1985-1995	6.8%	37.5%	n.a.	0.030	0.021	n.a.
	1995-1999	-0.6%	-3.7%	n.a.	-0.008	-0.036	n.a.
	1999-2004	8.9%	8.3%	13.5%	0.007	0.060	-0.051
20 Electrical machinery	1985-1995	26.7%	92.3%	n.a.	0.014	0.195	n.a.
	1995-1999	12.7%	2.9%	n.a.	-0.003	-0.187	n.a.
	1999-2004	25.9%	55.2%	14.1%	-0.010	0.058	-0.062
21 Motor vehicles	1985-1995	7.4%	48.4%	n.a.	-0.018	-0.005	n.a.
	1995-1999	1.1%	4.1%	n.a.	0.020	-0.059	n.a.
	1999-2004	5.6%	7.0%	13.9%	0.002	-0.027	0.102
22 Transportation equipment and ordnance	1985-1995	10.7%	35.9%	n.a.	0.017	-0.006	n.a.
	1995-1999	-3.1%	6.6%	n.a.	-0.001	0.034	n.a.
	1999-2004	6.5%	-13.4%	17.8%	0.008	-0.035	-0.115
23 Instruments	1985-1995	5.7%	36.9%	n.a.	0.017	0.040	n.a.
	1995-1999	0.9%	7.8%	n.a.	-0.010	0.007	n.a.
	1999-2004	7.1%	-3.5%	13.0%	-0.010	0.021	0.092
24 Rubber and misc. plastics	1985-1995	5.0%	22.0%	n.a.	0.007	-0.001	n.a.
	1995-1999	0.8%	5.8%	n.a.	0.005	0.024	n.a.
	1999-2004	4.3%	10.7%	7.1%	-0.001	0.096	0.042
25 Misc. manufacturing	1985-1995	8.2%	28.9%	n.a.	0.055	0.053	n.a.
	1995-1999	9.1%	7.0%	n.a.	-0.015	-0.081	n.a.
	1999-2004	18.7%	6.9%	-2.4%	0.031	0.020	0.095

Non-manufacturing Industry		TFP growth rate			Difference in the gap*		
		Japan	Korea	China	Japan	Korea	China
1 Agriculture	1985-1995	-11.1%	-58.7%	n.a.	-0.001	0.003	n.a.
	1995-1999	8.2%	-1.0%	n.a.	-0.004	-0.059	n.a.
	1999-2004	6.0%	-19.6%	-11.6%	0.009	0.021	0.149
2 Coal mining	1985-1995	-13.1%	-55.5%	n.a.	0.005	0.000	n.a.
	1995-1999	10.0%	6.6%	n.a.	-0.006	0.000	n.a.
	1999-2004	16.9%	46.8%	-34.1%	-0.003	0.000	-0.077
3 Metal and nonmetallic mining	1985-1995	-8.6%	n.a.	n.a.	0.002	n.a.	n.a.
	1995-1999	14.0%	n.a.	n.a.	0.018	n.a.	n.a.
	1999-2004	9.8%	n.a.	-8.6%	-0.036	n.a.	0.228
4 Oil and gas extraction	1985-1995	-45.3%	n.a.	n.a.	-0.117	n.a.	n.a.
	1995-1999	16.6%	n.a.	n.a.	-0.048	n.a.	n.a.
	1999-2004	40.3%	n.a.	-84.5%	0.075	n.a.	-0.484
5 Construction	1985-1995	-5.7%	-48.8%	n.a.	-0.019	0.077	n.a.
	1995-1999	-1.2%	-3.1%	n.a.	0.004	0.058	n.a.
	1999-2004	0.9%	-5.3%	-8.7%	0.015	-0.016	-0.091
26 Transportation	1985-1995	-1.3%	-3.7%	n.a.	-0.006	-0.058	n.a.
	1995-1999	3.3%	10.5%	n.a.	0.021	-0.141	n.a.
	1999-2004	9.0%	45.8%	24.7%	0.019	0.091	0.178
27 Communication	1985-1995	6.6%	125.1%	n.a.	-0.045	1.185	n.a.
	1995-1999	38.9%	41.5%	n.a.	0.117	0.242	n.a.
	1999-2004	-2.6%	63.9%	24.4%	-0.100	-0.009	0.070
28 Electrical utilities	1985-1995	-11.0%	93.6%	n.a.	-0.015	0.000	n.a.
	1995-1999	6.7%	-21.1%	n.a.	0.014	0.000	n.a.
	1999-2004	9.6%	-1.8%	2.3%	-0.025	0.000	0.044
29 Gas utilities	1985-1995	-23.3%	77.0%	n.a.	0.001	-0.618	n.a.
	1995-1999	-1.5%	-12.5%	n.a.	-0.006	-0.102	n.a.
	1999-2004	12.7%	8.5%	10.0%	-0.002	0.062	0.074
30 Trade	1985-1995	7.5%	22.0%	n.a.	-0.085	0.013	n.a.
	1995-1999	2.4%	10.9%	n.a.	-0.053	-0.081	n.a.
	1999-2004	14.1%	7.8%	9.5%	0.025	0.097	0.164
31 Finance, insurance and real estate	1985-1995	-13.1%	n.a.	n.a.	-0.056	n.a.	n.a.
	1995-1999	-0.7%	n.a.	n.a.	0.007	n.a.	n.a.
	1999-2004	1.1%	n.a.	14.2%	-0.011	n.a.	0.053
32 Other private services	1985-1995	-1.9%	-45.9%	n.a.	-0.004	0.023	n.a.
	1995-1999	8.8%	-0.4%	n.a.	0.017	-0.040	n.a.
	1999-2004	6.1%	3.9%	-1.6%	-0.015	0.115	-0.008
33 Public service	1985-1995	-24.6%	n.a.	n.a.	0.000	n.a.	n.a.
	1995-1999	-7.4%	n.a.	n.a.	0.000	n.a.	n.a.
	1999-2004	4.8%	n.a.	n.a.	0.000	n.a.	n.a.

*Difference between the starting year and the ending year during each period.



Center for China and Asian Studies
Nihon University College of Economics

1-3-2 Misaki-cho, Chiyoda-ku Tokyo 101-8360
Phone: +81-3-3219-3523
Fax: +81-3-3219-3529