Total Factor Productivity of Chinese Listed Firms and Catching up with Korean Listed Firms

Xu Jin *

In this paper, we measured the total factor productivity (TFP) of all Chinese publicly listed firms by micro-level, that is, by industry and firm levels, from 1999 to 2005. Financial data from the China Stock Market (CSMAR) database were used and capital (K), labor (L), and material (M) were employed as input factors. China's TFP showed some increase but remained relatively stagnant, mainly because of the low TFP of big firms, which could potentially drive the country's overall productivity. We used four patterns of catch-up method (*i.e.*, overtaking, convergence, slow catch-up, and reverse catch-up) developed by Jung and Lee (2010) to classify the catch-up patterns present in Chinese and Korean manufacturing industries. Two labor input methods, man hour and wage, were adopted for this purpose. The overall TFP catch-up level depended on the different labor input methods. Using man hour as labor input, no catch-up occurred in the overall industry level. Only "slow catch-up" and "reverse catch-up" manifested, indicating a huge gap between the overall industry TFPs of the two countries. Meanwhile, using wage as labor input, all of the four catch-up patterns occurred. The apparel industry particularly showed an "overtaking," and four industries, namely, electrical machinery, textile mill products, instruments, and petroleum and coal products, showed a "convergence" pattern. The catch-up level of Chinese manufacturing firms approached that of Korean firms when wage was used as labor input.

Keywords: Productivity, Catch-up, Chinese firms, Korean firms, PPP, ICPA code

JEL Classification: D24, L25, O57

* Assistant Professor, Division of International Studies, Konkuk University, 120 Neungdong-ro, Gwangjin-gu, Seoul 143-701, Korea, (Tel) +82-2-450-0462, (Fax) +82-2-450-4044, (E-mail) jinxv0706@gmail.com.
[**Seoul Journal of Economics** 2012, Vol. 25, No. 2]

I. Introduction

Since China joined the World Trade Organization (WTO), the globalization of Chinese firms has rapidly progressed. In 2005, 15 Chinese mainland firms were listed in the Fortune 500,[1] and China has been called the "factory of the world." The influence and power of China in East Asia has improved significantly, allowing Chinese firms to challenge their Japanese and Korean counterparts.

In recent years, the need to conduct a comparative analysis of the productivity of Chinese and Korean firms has gathered much attention. The analysis of industry-level total factor productivity (TFP) in China has been showing an increasing trend since 2000. However, a data problem is encountered when measuring the TFP of Chinese mainland firms at the industry level. Most of the industry-level data were from China's National Bureau of Statistics (NBS), which was the only source of information on years prior to 1978. During those times, the Soviet-style industry classification method was used for data collection in China. From 1984 to 1994, China reclassified industries to follow the International Standard Industrial Classification (ISIC). Hence, the only available industry-level data complying with the ISIC standard are those from 1978. As such, the TFP study is limited by short-term and inconsistent data. Obtaining consistent and long-term data resources outside the NBS database is difficult. Holz (2004) pointed out that deviations would be encountered in macro-level empirical analysis, that is, macro-level data would be difficult to treat as the sum of micro-level data.

The present paper aims to calculate the TFP at the firm level using financial data of listed firms in China from the China Stock Market (CSMAR). Capital (K), labor (L), and material (M) were employed as input factors. The Chinese TFP trend was compared with that of Korean manufacturing firms using the chain-linked method developed by Good *et al.* (1996) to examine whether the Chinese mainland can catch up with the Korean economy. Moreover, four patterns of catch-up method, namely, overtaking, convergence, slow catch-up, and reverse catch-up, were identified by adopting the method developed by Jung and Lee (2010). The results of the study by Fukao *et al.* (2009), who employed data on purchasing power parity (PPP) from the International Comparison of Productivity among Asian countries (ICPA) Project, were used in the current study. Financial data on Korean listed firms were sourced from the

[1] http://money.cnn.com/magazines/fortune/global500/2005/countries/C.html

KOSPI (Korea Composite Stock Price Index) and KOSDAQ (Korea Securities Dealers Automated Quotations) databases. Man hour and wage were used as labor inputs. Usage of employee number and labor hours as labor inputs showed a huge gap in TFP between Chinese and Korean firms at around 60% to 80% from 1999 to 2005. The patterns were limited to only "slow catch-up" and "reverse catch-up." Considering that labor wage in Korean manufacturing firms was approximately ten times higher than that in Chinese firms, measuring TFP level using labor wage instead of number of employees as input is similarly important.

Man hour used as labor input produced the following results. First, no catch-up occurred in the overall industry level from 1999 to 2005. The TFP of listed Chinese manufacturing firms was 60% to 80% of that of Korean firms. By the end of 2005, the average TFP level and the weighted average TFP level of listed Chinese manufacturing firms stood at only 28.1% and 41.3%, respectively, of those of Korean firms. Second, "slow catch-up" and "increasing gap" were manifested, indicating the large overall industry TFP gap between the two countries.

Meanwhile, using wage as labor input showed different results. First, the TFP of Chinese manufacturing firms in 1999 was 30% lower than that of Korean manufacturing firms, and the figure decreased consistently until it reached 20% by the end of 2005. Clearly, the TFP gap became narrow. The average TFP level of Chinese manufacturing listed firms stood at only 71.5% of that of Korean firms by the end of 2005. Second, all of the four catch-up patterns occurred. The apparel industry showed an "overtaking" pattern. Four industries, namely, electrical machinery, textile mill products, instruments, and petroleum and coal products, showed a "convergence" pattern. Four industries, namely, printing, publishing, and allied, motor vehicles, fabricated metal, and non-electrical machinery, showed a "slow catch-up" pattern. Lastly, the remaining eight industries, namely, rubber and misc plastics, primary metal, miscellaneous manufacturing, chemicals, stone clay glass, transportation equipment, and paper and allied, showed a "reverse catch-up" pattern.

The present paper is organized as follows: Section 2 reviews previous literature, and Section 3 describes the data for TFP measurement and method. The results of the TFP measurement are provided in Section 4. Section 5 defines internationally comparable TFP and four TFP catch-up patterns to compare the TFP of Chinese and Korean listed manufacturing firms. Comparison results are presented in Section 6. Section 7 concludes the paper with a brief summary.

II. Literature Survey

Studies on industry-level TFP in China have been increased since 2000. However, analyses of micro-level productivity using Chinese firm-level data are very limited. Many previous analyses were based on data from the NBS of China, and these studies only used capital (K) and labor (L) factors as productivity inputs. As such, analyses were mostly limited to individual and firm-level productivity. More recently, we are seeing some studies focused on the micro-level TFP, especially the firm-level TFP of Chinese firms.

A. Industry-Level Productivity Study

Studies on the initial stage of industry-level productivity mainly focused on state-owned firms. Kuan *et al.* (1988) first calculated industry-level productivity of Chinese state-owned firms from 1953 to 1985. The results of their study showed that the annual average TFP growth rate stood at 1.3%. Jefferson *et al.* (1996) calculated the industry-level productivity of Chinese state-owned and group firms. They found that the annual average TFP growth rate stood at 2.5%. Wang and Szirmai (2008) examined three types of structural changes: in the sectoral structure of production, in the ownership structure, and in the regional structure of production. Overall productivity growth was slow in the 1980s, but accelerated dramatically from 1990 onwards. They found evidence of a structural change bonus in the 1980s, with sectoral shifts contributing 24% in the overall productivity growth. However, this shift effect contribution dropped to a mere 3.3% when productivity growth accelerated in the 1990s. Other existing literature are those from Cao *et al.* (2009). They calculated the average annual industry-level Chinese TFP growth rate to be at 2.5%. The study by Ren and Sun (2006) was one of those conducted under the ICPA project of the Research Institute of Economy, Trade and Industry (RIETI) in Japan, which was based on 33 industry classifications in ICPA. The study calculated the industry-level Chinese TFP growth from 1981 to 2000, and found that the annual average growth rate was 3.22%. That study was the first one to use K, L, and M as productivity input factors. Motohashi (2005), using the database of Ren and Sun (2006) as basis, compared the TFP growth rates of five countries, namely, China, Korea, Japan, Taiwan, and the United States. In the study, the industry-level Chinese annual average TFP growth stood at 0.76% from 1980 to 2002. Wu (2007) calculated the TFP growth rate from 1980 to

2005, which was found to be -0.9% from 1980 to 1993. This rate improved to 6.1% from 1993 to 2005. From his analysis, Wu determined that the productivity increase was caused by China's accession to the WTO in 2001. Ozyurt (2009) calculated the Chinese industry-level TFP growth rate from 1952 to 2005, and found that the annual average growth rate stood at 0.2% from 1952 to 1992, but improved to 3.8% from 1993 to 2005.

B. Firm-Level Productivity Study

Gordon and Li (1995) used a panel data set of 403 firms in estimating the change in productivity of Chinese state enterprises from 1983 to 1987. Chinese productivity increased by 4.6% per year. Several Chinese scholars began to conduct firm-level Chinese TFP studies in 2007. Some scholars used capital (K), labor (L), and material (M) as productivity inputs, but many overseas scholars were still limited to using the first two inputs (*e.g.*, Jefferson *et al.* (2008), Brandt *et al.* (2009), Hsieh and Klenow (2009), *etc.*). Studies using firm-level data and the input variables of capital (K), labor (L), and material (M) are mentioned below.

Another study conducted under the RIETI's ICPA project was that by Yuan *et al.* (2007), which first used the CSMAR database to calculate industry- and firm-level TFPs of Chinese listed manufacturing firms. The TFP level of all listed manufacturing firms increased from 1999 to 2004. Yu (2008) calculated TFP based on data on 150,000 Chinese manufacturing firms from 1998 to 2002, as provided by the NBS. According to Yu, free trade has had a positive effect on TFP growth. Li and Yu (2009) calculated the TFP based on NBS data on 160,000 Chinese manufacturing firms from 2000 to 2007. They found that productivity could affect exports through credit constraints.

III. Data for TFP Measurement and Method

In the present study, we used data from the financial database of CSMAR provided by the Guo Tai An Group in China to measure the TFP of Chinese listed firms. The data used were from 1999 to 2005, as China had firm-level finance system reforms four times from 1990 to 1998, and the CSMAR database provided the employee numbers of each firm from 1999. Moreover, the labor wage data from 1998 were available in the cash flow statements obtained from the CSMAR database.

The existing literature on the methodology of measuring TFP in China

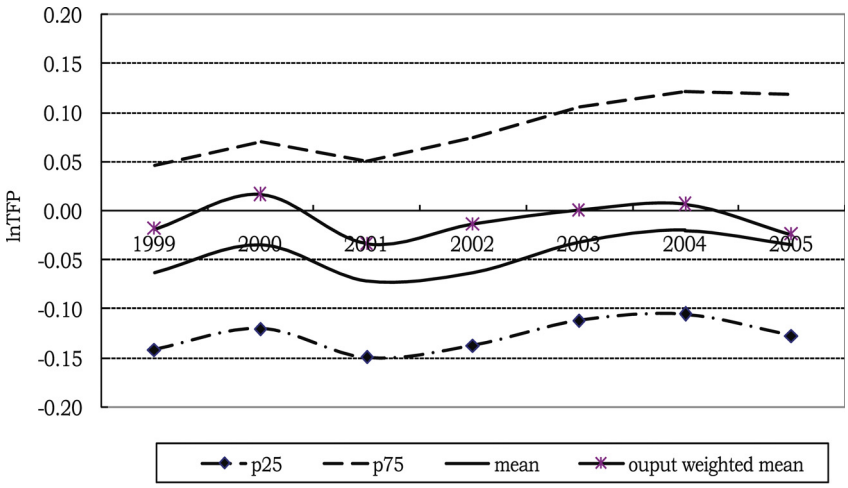


FIGURE 1
TOTAL MEAN AND OUTPUT WEIGHTED MEAN OF AVERAGE LNTFP LEVEL TREND

are as follows: (1) Malmquist index numbers method in Zheng and Hu (2006), Fu and Floor (2004), Zheng *et al.* (2003), and Fu and Gong (2009); (2) stochastic frontier (SF) in Rae *et al.* (2006) and Zhou and Han (2008); (3) data envelopment analysis (DEA) in Cheng and Lo (2004), Cheng (2006), and Qiu *et al.* (2009); (4) semi-parametric estimation (OP) in Yu (2008) and Li and Yu (2009), and so on. The present study followed the methodology of Good *et al.* (1996) and Aw *et al.* (2001), as well as extended the equation of TFP measuring methodology from Fukao *et al.* (2009), which was the result of the JCER project.[2]

IV. Result of Measurement

Table 1 and Figure 1 show the average lnTFP trends. The average lnTFP of China was increasing, but at a very slow rate. That is to say, the annual average lnTFP of listed firms in China increased by 2.8% and the annual weighted average of lnTFP rose by only 0.9% from 1999

[2] JCER project: Japan Center for Economic Research (JCER) East Asian Listed Companies Database 2009. Creation of a Productivity Database on Japanese, Chinese, and South Korean Companies along with the Hitotsubashi University Center for Economic Institutions (CEI), the CENU Center for China and Asian Studies, and the Center for Corporate Competitiveness of Seoul National University.

TABLE 1
AVERAGE LNTFP LEVEL

year	N	mean	Output weighted mean	Sd	min	p25	p75	max
1999	736	-0.063	-0.018	0.217	-2.003	-0.141	0.046	0.755
2000	842	-0.035	0.017	0.231	-2.897	-0.120	0.070	1.021
2001	915	-0.071	-0.033	0.268	-2.746	-0.149	0.051	1.200
2002	995	-0.063	-0.014	0.340	-3.600	-0.137	0.074	1.442
2003	1045	-0.032	0.000	0.305	-3.619	-0.112	0.106	1.887
2004	1121	-0.020	0.007	0.331	-3.972	-0.105	0.122	1.305
2005	1104	-0.035	-0.024	0.292	-3.633	-0.127	0.119	0.999
Total	6758	-0.044	-0.009	0.292	-3.972	-0.126	0.090	1.887

Source: Author's calculation.

TABLE 2
TFP LEVEL BY INDUSTRY (FIRM-LEVEL OUTPUT WEIGHTED MEAN)

ICPA code	Industry name	1999	2000	2001	2002	2003	2004	2005	1999-2005
1	Agriculture	0.01	0.01	-0.08	-0.12	-0.09	-0.11	-0.05	-0.09
2	Coal mining	0.02	0.02	-0.16	-0.13	-0.17	-0.12	-0.32	-0.03
3	Metal and nonmetallic mining	-0.06	0.1	0.21	0.19	0.11	-0.04	-0.14	-0.20
4	Oil and gas extraction	0.01	-0.12	-0.53	-0.5	-0.3	-0.71	-0.97	-0.24
5	Construction	-0.01	0	-0.02	-0.03	-0.07	-0.04	-0.05	-0.01
6	Food and kindred products	-0.02	0.02	0.01	0.03	0.02	0	0	-0.01
7	Textile mill products	0.01	-0.04	-0.05	-0.02	-0.01	-0.02	-0.01	0.05
8	Apparel	0.1	0.12	0.09	0.09	0.1	0.15	0.17	0.09
9	Lumber and wood						0	-0.01	-0.07
10	Furniture and fixtures	0	0.06	0	-0.2	-0.22	-0.11	-0.14	-0.03
11	Paper and allied	0.01	0.05	0	0.02	0.05	0.08	0.03	-0.03
12	Printing, publishing, and allied	-0.02	-0.03	-0.3	-0.09	-0.21	-0.04	0.01	-0.04
13	Chemicals	-0.01	0.01	0.01	0.03	0.05	0.03	0.02	0.03
14	Petroleum and coal products	0.01	0.10	-0.03	-0.01	0.03	0.11	0.06	0.01

(Continued)

TABLE 2
(CONTINUED)

ICPA code	Industry name	1999	2000	2001	2002	2003	2004	2005	1999-2005
15	Leather	0	-0.03	-0.01	-0.02	0.01	-0.01	-0.09	0
16	Stone clay glass	-0.03	0.02	0.01	0	0.05	0.06	0.03	0
17	Primary metal	-0.02	0.02	-0.01	0.04	0.01	-0.06	-0.07	0.06
18	Fabricated metal	0.13	0.26	0.02	0.19	0.03	0.28	0.07	0.11
19	Machinery, non-elect	0	0.04	0.05	0.05	0.11	0.16	0.17	0.07
20	Electrical machinery	-0.02	0.01	0.02	0.06	0.1	0.12	0.12	0.05
21	Motor vehicles	-0.01	-0.02	0	0.03	0.09	0.13	0.13	0.08
22	Transportation equipment and ordnance	0.01	0.02	0.08	0.1	0.13	0.18	0.22	0.07
23	Instruments	-0.01	0.03	0.01	0.01	0.08	0.05	0.08	0.02
24	Rubber and misc plastics	-0.05	-0.02	-0.01	0.03	0.04	0.04	0.01	-0.11
25	Misc manufacturing	-0.17	-0.18	-0.21	-0.25	-0.21	-0.24	-0.25	-0.21
26	Transportation	-0.24	-0.24	-0.26	-0.22	-0.22	-0.13	-0.14	-0.06
27	Communication	-0.03	0.01	0.05	0.07	0.14	0.18	0.16	0.06
28	Electrical utilities	-0.01	-0.01	0.09	0.04	0.08	0.05	0.04	0.02
29	Gas utilities	-0.06	0	0.02	-0.05	-0.02	0.04	0.04	0.09
30	Trade	-0.03	0.28	0.02	0.25	0.4	0.22	0.17	0.12
31	Finance insurance and real estate	0.01	0	0.05	0.07	0.08	0.09	0.09	-0.02
32	Other private services	-0.08	0.02	-0.08	-0.14	-0.19	-0.12	-0.15	-0.11

Source: Author's Calculation.

to 2005. The rate of increase shows relative stagnation, implying that the emergence of Chinese firms in the global market in recent years could not be attributed to high level of productivity. Figure 1 shows the widening gap of p25 and p75's quintile lnTFP level.

Table 2 shows the TFP trend and distributions per industry based on the ICPA standard. Based on this table, we can determine that TFP gaps exist not only between firms in the same industry, but also in between industries. Some industries, such as those involved in electrical machinery, motor vehicles, non-electrical standard machinery, transportation

equipment and ordnance, communications, trade, and so on, showed a small increase in TFP level. Some industries with a small number of firms, such as those involved in lumber and wood, furniture and fixtures, and leather, showed unstable TFP distribution.

V. Methodology Used to Compare the TFP of Chinese and Korean Listed Manufacturing Firms

A. Measuring the Internationally Comparable TFP

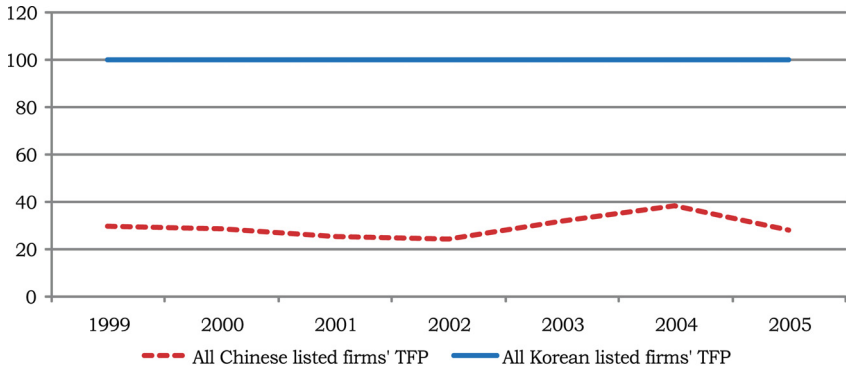
This paper analyzed the TFP gap between Chinese and Korean listed manufacturing firms using the chain-linked time index. Good *et al.* (1996) first used the chain-linked time index number method in their study. Using this method, Schreyer (2005) compared international productivity, and Jung *et al.* (2008) calculated the TFP gap between listed manufacturing firms in Korea and Japan. Jung and Lee (2010) defined TFP catch-up as having four patterns, namely, overtaking, convergence, slow catch-up, and reverse catch-up. TFP was calculated in the present thesis using two methods: one that used man hour as labor input, and another that used wage. The TFP gap between China and Korea was measured and analyzed using the four catch-up patterns mentioned above. PPP rate was computed using the ICPA calculation method used in the study by Fukao *et al.* (2009).

B. Data

This paper used data on manufacturing parts industry of Chinese and Korean listed firms from the 1999 to 2005, and mapped industry codes used in both two counties to international standard industry code (ICPA 6-25). The period covered was from 1999 to 2005, with the year 2000 as the base year. Data on the TFP of Korean firms were obtained from the study by Bak *et al.* (2009), which was part of the JCER project using financial data on firms listed in KOSPI and KOSDAQ provided by KIS (Korea Investors Service, www.kisvalue.co.kr). Similar to that of Chinese firms, the TFP of Korean firms also involved the use of manufacturing parts from the 1999 to 2005 map to ICPA 6-25.

C. Defining TFP Catch-up Index

The TFP catch-up index was defined following Good *et al.* (1996), Schreyer (2005), and Jung *et al.* (2008). The TFP catch-up index showed



Note: The TFP level of all Korean listed firms in each year was set at 100. The difference can be regarded as a percentage gap in TFP between the two countries because the values are natural log values of TFP.

FIGURE 2
TFP CATCH-UP INDEX 1 OF ALL MANUFACTURING LISTED FIRMS (SIMPLE AVERAGE)

the TFP level gap between two countries in the same industry. The value was the natural log value, and could then be interpreted as the percentage difference between the TFP of the two countries.

D. Four TFP Catch-up Patterns

Following Jung and Lee (2010), we classified the patterns of TFP catch-up between Chinese and Korean firms into four: "overtaking," "convergence," "slow catch-up," and "reverse catch-up." As shown in Table 3 and Figure 3, the X-axis measures the percentage gap between a Chinese sector and a Korean sector in the first year (1999), and the Y-axis measures its change (reduction) over time, that is, the TFP gap in 1999 minus the TFP gap in 2005.

Equation (1):

$Y-X>10$ and $Y\geq 0$: Overtaking (TFP of Chinese firms is more than 10% higher than that of Korean firms)

$-10\leq Y-X\leq 10$ and $Y\geq 0$: Convergence (TFP gap is within the 10% range)

$Y-X<-10$ and $Y\geq 0$: Slow catch-up (the gap is maintained at over 10%)

$Y<0$: Reverse catch-up (the gap increased)

TABLE 3
FOUR PATTERNS OF TFP CATCH-UP 1

ICPA code	Industry name	1999	2000	2001	2002	2003	2004	2005	Initial gap (X)	TFP reduc-tion(Y)	Catch-up pattern
14	Petroleum and coal products	53.2	87.5	65.2	64.7	132.7	87.4	77.7	46.8	24.5	Slow Catch-up
18	Fabricated metal	59	61.5	74.2	59.7	48.1	65.7	60.9	41	1.9	Slow Catch-up
19	Machinery non-elect	-31	-12.9	-19.1	-14.2	-8.4	8.6	14.5	131	45.5	Slow Catch-up
20	Electrical machinery	52.6	50.6	56.5	61.8	69.7	75.3	69.7	47.4	17.1	Slow Catch-up
21	Motor Vehicles	34.5	4.7	31.2	33.5	42.2	51.4	50.4	65.5	15.9	Slow Catch-up
23	Instruments	34.6	35.3	35.1	21.7	31.8	52.8	57.9	65.4	23.3	Slow Catch-up
6	Food and kindred products	57.4	60.9	55.8	55.4	49.1	51.2	44.5	42.6	-12.9	Reverse Catch-up
7	Textile mill products	69.5	62.4	57.8	44.7	55.9	63.1	53.6	30.5	-15.9	Reverse Catch-up
8	Apparel	140.8	85.1	152.9	111.6	174.2	171.2	122.9	-40.8	-17.9	Reverse Catch-up
10	Furniture and fixtures	-22.2	-27.2	-40.6	-73.7	-80.4	-51.7	-69.6	122.2	-47.4	Reverse Catch-up
11	Paper and allied	69.8	55.4	46.4	53	65.1	60.1	-10	30.2	-79.8	Reverse Catch-up
12	Printing, publi-shing, and allied	50.6	37.2	0	-57.5	-8.9	36.6	32.2	49.4	-18.4	Reverse Catch-up
13	Chemicals	15.4	12.8	2.7	3.7	10.8	14.3	3.8	84.6	-11.6	Reverse Catch-up
15	Leather	173.9	154.9	145.5	150.8	148.7	154.3	132.1	-73.9	-41.8	Reverse Catch-up
16	Stone clay glass	1.2	-2.6	-3.2	-8.4	-6.6	0.4	-7.9	98.8	-9.1	Reverse Catch-up
17	Primary metal	72.8	75.9	60.9	68.7	71.3	60.2	57.7	27.2	-15.1	Reverse Catch-up
22	Transportation equipment	7.1	-17.9	-25.2	-2.6	8.4	20.2	-15.2	92.9	-22.3	Reverse Catch-up
24	Rubber and misc plastics	92.7	89.4	92.6	97.4	97.3	96.7	91.5	7.3	-1.2	Reverse Catch-up
25	Misc manufacturing	27.9	14.4	3.6	-1.8	14.4	18	18	72.1	-9.9	Reverse Catch-up
Total		50.5	43.5	41.7	35.2	48.2	54.5	41.3	49.5	-9.2	

Source: Author's calculation.

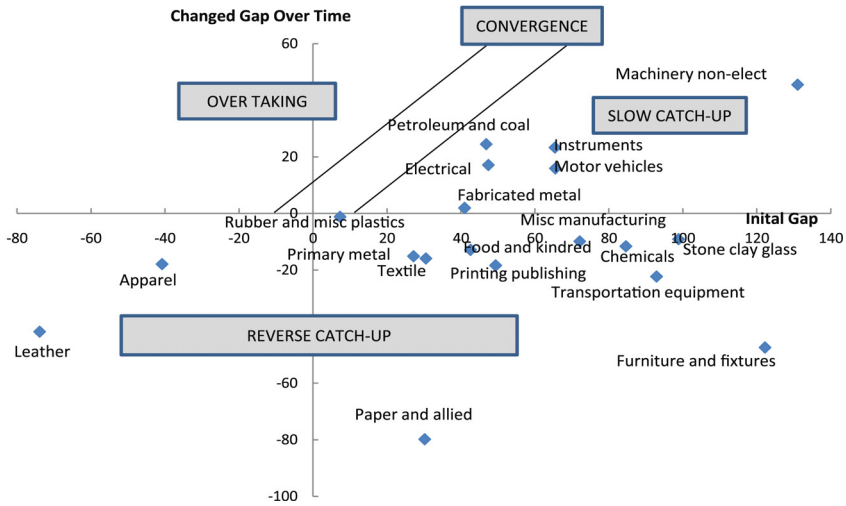


FIGURE 3
DEFINING FOUR PATTERNS OF TFP CATCH-UP 1
(WITH MAN HOUR AS LABOR INPUT)

VI. Result of TFP Catch-up and the Four Patterns of Catch-up

A. Overall Result by Firm Size (with man hour as labor input)

Figure 2 shows the simple average of the catch-up index by firm size when the labor input is man hour. The TFP gap between Chinese and Korean manufacturing firms ranged from 80% to 60% from 1999 to 2005. The figures show some catch-up from 2002, with the gap widening again in 2005.

B. Four Patterns of Catch-up 1 (with man hour as labor input)

Based on Table 3, we can identify the four patterns of catch-up, namely, "overtaking," "convergence," "slow catch-up," and "reverse catch-up." Figure 3 shows the results.

As seen from Table 3 and Figure 3, the distribution is only limited to the two patterns of "slow catch-up" and "reverse catch-up." No industry shows "overtaking" and "convergence," unlike for Korean firms. Hence, a large gap in TFP still exists between Chinese and Korean firms.

TABLE 4
LABOR WAGES IN CHINESE AND KOREAN MANUFACTURING FIRMS FROM 1999 TO 2001

Year	Korean	Chinese	Ratio	
	Wage ($)	Wage ($)	vs. average of total China	vs. coastal cities in China
1999	1,240	78	15.8	11.1
2000	1,416	88	16.1	11.2
2001	1,319	98	13.4	9.4

Note: Ten coastal cities include Beijing, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Hainan, and so on.
Source: Cheong and Lee (2003).

(a) Pattern 1: "Overtaking"

The first pattern of catch-up is "overtaking," which occurs when the TFP of Chinese firms in a certain industry exceeds that of their Korean counterparts by more than 10%. As we can see in Table 3 and Figure 3, no "overtaking" occurred between Chinese and Korean firms.

(b) Pattern 2: "Convergence"

The second pattern is called "convergence," which occurs when the TFP of Chinese firms in a certain industry converges with that of Korean firms. Therefore, the gap in TFP is within the 10% range. As seen from Table 3 and Figure 3, no "convergence" occurred between Chinese and Korean firms.

(c) Pattern 3: "Slow Catch-up"

The third pattern is "slow catch-up," which occurs when the TFP gap between the two countries is maintained at more than 10%. Six Chinese industries, particularly those involved in petroleum and coal products, fabricated metal, machinery non-elect, electrical machinery, motor vehicles, and instruments, showed "slow catch-up" against Korean counterparts.

(d) Pattern 4: "Reverse Catch-up"

Sectors in this pattern show "negative" catch-up performance during the period, indicating a widening TFP gap. "Reverse catch-up" is evident when 12 Chinese industries, namely, food and kindred products, textile mill products and apparel, furniture and fixtures, paper and allied, prin-

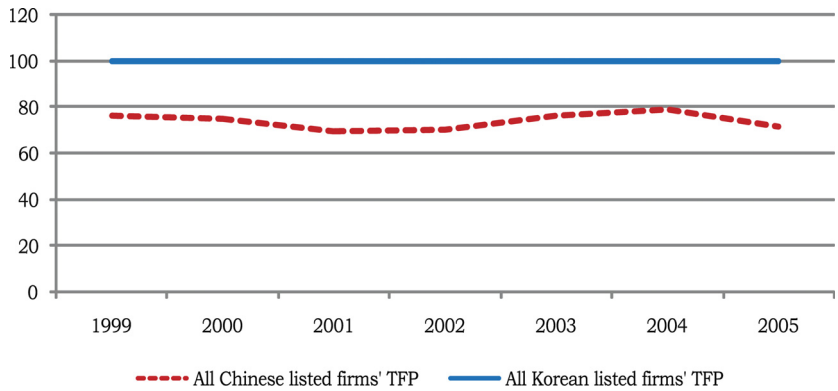


FIGURE 4
TFP CATCH-UP INDEX 2 OF ALL LISTED MANUFACTURING FIRMS (SIMPLE AVERAGE)

ting, publishing, and allied, chemicals, leather, stone clay glass, primary metal, transportation equipment, rubber and miscellaneous plastics, and miscellaneous manufacturing, were compared against their Korean counterparts.

C. Overall Result by Firm Size (with wage as labor input)

We used employee number and labor hours as labor inputs in calculating the TFP of Chinese and Korean firms. The TFP gap between Chinese and Korean firms was very large at around 60% to 80% from 1999 to 2005. Patterns were limited to "slow catch-up" and "reverse catch-up." According to Cheong and Lee (2003), average labor wage in Korean manufacturing firms was 13.4 times higher than that in Chinese manufacturing firms and 9.4 times higher than that in Chinese coastal cities in 2001.

Considering that labor wage in Korean manufacturing firms was around ten times higher than that in Chinese firms, measuring TFP level using labor wage instead of number of employees as input,[3] is likewise important. We applied the PPP rate in Fukao *et al.* (2009) to calculate the TFP catch-up index between Korean and Chinese manufacturing firms.

Figure 4 shows the re-calculated TFP catch-up index and the trend

[3] The labor wage current exchange rates used were the market current exchange rates between China and Korea from 1999 to 2005. Data were provided by the Bank of Korea.

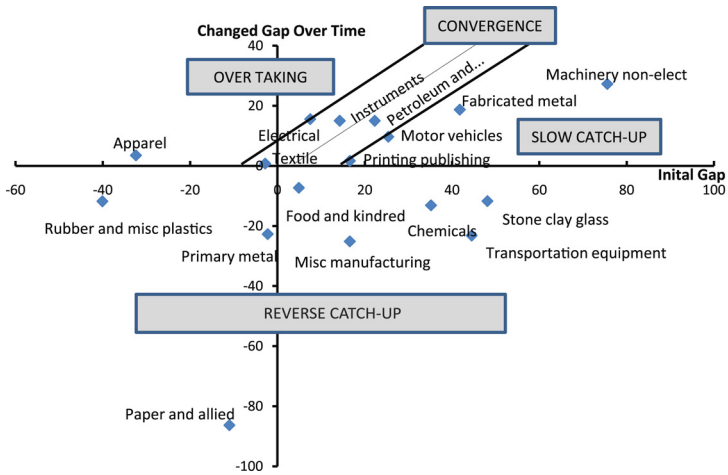


FIGURE 5

DEFINING FOUR PATTERNS OF TFP CATCH-UP 2
(WITH WAGE AS LABOR INPUT)

by simple average. The TFP gap between Korean and Chinese manufacturing firms from 1999 to 2005 narrowed to a range of 20% to 30%. In 2005, for instance, the average TFP of Chinese manufacturing firms was 71.5% of that of Korean firms, as shown in Figure 4.

D. Four Patterns of Catch-up 2 (with wage as labor input)

Based on Table 5, we can identify the four patterns of catch-up, namely, "overtaking," "convergence," "slow catch-up," and "reverse catch-up." Figure 5 shows the results.

From Table 5 and Figure 5, we see that one industry shows "overtaking," four industries show "convergence," four industries show "slow catch-up," and eight industries show "reverse catch-up."

(a) Pattern 1: "Overtaking"

The first pattern of catch-up defined in this paper is "overtaking," which means that the TFP of the Chinese firms in that industry was higher than the 10% margin of Korean firms. Overtaking is the result of the impressive and positive catch-up performance of Chinese firms. Only the apparel industry showed "overtaking," as it exceeded 32% of the TFP performance in the initial year and maintained the same gap until 2005. As shown in Table 6, the share of the apparel industry in the total

TABLE 5

FOUR PATTERNS OF TFP CATCH-UP 2

ICPA code	Industry name	1999	2000	2001	2002	2003	2004	2005	Initial gap (X)	TFP reduction(Y)	Catch-up pattern
8	Apparel	132.4	77.6	148	103	168	165.5	135.9	-32.4	3.5	Overtaking
20	Electrical machinery	92.5	87.5	94.5	100.1	107.3	113.6	108.1	7.5	15.6	Conversense
7	Textile mill products	102.8	101.9	100.4	86.5	99.4	104.4	103.6	-2.8	0.8	Conversense
23	Instruments	85.7	80.6	87.8	72.8	81.4	92.0	100.7	14.3	15.0	Conversense
14	Petroleum and coal products	77.7	109.2	79.2	86.7	151.2	105.2	92.7	22.3	15.0	Conversense
12	Printing, publishing, and allied	83.4	82	46	-10.9	48.1	96.3	85.1	16.6	1.7	Slow Catch-up
21	Motor Vehicles	74.6	45.2	71.8	73.8	78	85.7	84.3	25.4	9.7	Slow Catch-up
18	Fabricated metal	58.2	52.8	72.7	55.8	60.9	54.2	76.9	41.8	18.7	Slow Catch-up
19	Machinery non-elect	24.4	38.8	30.6	33.8	32.8	44.8	51.7	75.6	27.3	Slow Catch-up
24	Rubber and misc plastics	140.1	130.4	130.1	134.2	136.5	134.2	128.3	-40.1	-11.8	Reverse Catch-up
6	Food and kindred products	95.1	99.2	90.5	89.2	84.0	90.1	87.8	4.9	-7.3	Reverse Catch-up
17	Primary metal	102.2	101.9	88	95.4	97.4	81.9	79.5	-2.2	-22.7	Reverse Catch-up
25	Misc manufacturing	83.4	70.6	66.1	50.9	60	57.3	58.3	16.6	-25.1	Reverse Catch-up
13	Chemicals	64.8	64	52.7	53.5	59.2	59.6	51.7	35.2	-13.1	Reverse Catch-up
16	Stone clay glass	51.9	47	41.9	45.2	46.7	45.8	40.2	48.1	-11.7	Reverse Catch-up
22	Transportation equipment	55.5	40.1	29.6	50.3	62.1	70.6	32.3	44.5	-23.2	Reverse Catch-up
11	Paper and allied	111	97.3	89.5	94.2	102.5	96.7	24.7	-11	-86.3	Reverse Catch-up
	Total	84.5	78.0	77.6	71.4	86.8	88.1	78.9	15.5	-5.5	

Note: Industry map to ICPA code 9, 10, and 15 were excluded.

number of firms and to the total amount of sales in the Chinese manufacturing sector was 1.9% and 1.0%, respectively. Evidently, China was highly competitive in the traditional labor-intensive industry, although its economy of scale was not sufficiently large. The leading firm in this industry was the Youngor Group, which accounted for 23.5% of the sales revenue of the apparel industry, already exceeding the average TFP level of the Korean apparel industry in 1999.

(b) Pattern 2: "Convergence"

The second pattern is called "convergence," which means that the TFP of Chinese firms in that industry converged with that of Korean firms, and that the TFP gap was within the 10% range. The industries belonging to this pattern are shown as the band marked by two 45-degree parallels in the XY space, each starting from the (-10, 0) and (10, 0) points, respectively. The industries that showed this catch-up pattern were those involved in electrical machinery, textile mill products, instruments, and petroleum and coal products. As shown in Table 6, the shares of the four industries were 25.4% and 26.8%, respectively, out of the total number of firms and to the amount of sales of the Chinese manufacturing sector. For electronics, the figures were 17.9% and 18.0%, respectively. The leading firms in these four industries were the TCL Corporation, Shanghai Shenda, Holly Pharmaceuticals (Chongqing), and Sinopec Shanghai Petrochemical Company Ltd. For the Chinese electronics industry, the TFP level improved from 92.5% to 108.1% from 1999 to 2005. As shown in Table 6, the share of TCL to the total industry sales was only 13.9%, indicating that China had more competitive firms, such as Haier and ZTE, with the same level of productivity as that of TCL distributed among all the industries. Korea had two dominant leading firms, namely, Samsung and LG Electronics.

(c) Pattern 3: "Slow Catch-up"

The third pattern is "slow catch-up," wherein the TFP gap between the two countries remained over 10%. The industries belonging to this pattern are shown in the upper right section of the XY space. As shown in Table 5 and Figure 5, industries that manifested this pattern were those in printing and publishing, motor vehicles, fabricated metal, and non-electrical machinery. As shown in Table 6, the shares of those industries to the total number of firms and to the total amount of sales of the Chinese manufacturing sector were 17.2% and 38.3%, respectively. An example of this sector is the fabricated metal industry, which grew

TABLE 6

FIRM NUMBER, SALES, AND LARGEST FIRM IN EACH CATCH-UP PATTERN (CHINA)

ICPA code	Catch-up pattern	Industry name	Number of firms in each Ind 2005		Ind Sum of Sales in 2005		Largest Sales Firms in each industry	Sale of Top Firm	
			Number	Ind sum/ Total (%)	Billion Y, 2005 price	Ind sum/ Total (%)		Billion Y, 2005 price	Each Firm/ Ind sum (%)
8	Overtaking	Apparel	16	1.9	19.7	1.0	Youngor Group	4.6	23.5
	Sum		**16**	**1.9**	**19.7**	**1.0**		**4.6**	**23.5**
20	Convergence	Electrical machinery	149	17.9	371.4	18.0	TCL Corporation	51.7	13.9
7	Convergence	Textile mill products	39	4.7	45.1	2.2	Shanghai Shenda	5.0	51.0
23	Convergence	Instruments	11	1.3	8.8	0.4	HOLLEY PHARMACEUTICALS (CHONGQING)	2.7	27.6
14	Convergence	Petroleum and coal products	12	1.4	127.6	6.2	Sinopec Shanghai Petrochemical Company Limited	45.9	472.1
	Sum		**211**	**25.4**	**552.9**	**2.1**		**105.2**	**1082.5**
12	Slow catch-up	Printing, publishing, and allied	4	0.5	1.2	0.1	SHANGHAI JIELONG INDUSTRY GROUP	0.6	51.8
21	Slow catch-up	Motor Vehicles	37	4.5	136.7	6.6	Chongqing Changan Automobile	19.2	14.0
18	Slow catch-up	Fabricated metal	15	1.8	54.3	2.6	CHINA INTERNATIONAL MARINE CONTAINERS	31.0	57.1
19	Slow catch-up	Machinery non-elect	87	10.5	114.2	5.5	Shanghai Zhenhua Port Machinery	12.1	10.6
	Sum		**143**	**17.2**	**306.5**	**38.3**		**62.9**	**20.5**
24	Reverse catch-up	Rubber and misc plastics	25	3.0	43.5	2.1	Shanghai Tyre & Rubber	5.1	11.7
6	Reverse catch-up	Food and kindred products	59	7.1	106.7	5.2	Henan Shuanghui Investment & Development	13.5	12.6
17	Reverse catch-up	Primary metal	58	7.0	638.3	30.9	Baoshan Iron & Steel	127.0	19.9
25	Reverse catch-up	Misc manufacturing	17	2.0	13.5	0.7	CHINA FIRST PENCIL	2.9	21.7
13	Reverse catch-up	Chemicals	207	24.9	278.5	13.5	Sinopec Yizheng Chemical Fibre	15.8	5.7
16	Reverse catch-up	Stone clay glass	50	6.0	48.3	2.3	ANHUI CONCH CEMENT	10.8	22.4
22	Reverse catch-up	Transportation equipment and ordnance	22	2.6	28.3	1.4	XIAMEN KING LONG MOTOR GROUP	7.7	27.3
11	Reverse catch-up	Paper and allied	23	2.8	30.2	1.5	SHANDONG CHENMING PAPER HOLDINGS	9.7	32.2
	Sum		**461**	**55.5**	**1187.3**	**18.6**		**192.6**	**16.2**
	Total		**831**	**100.0**	**2066.4**	**100.0**		**538.1**	**26.0**

Note: ICPA code 9, 10, and 15 were excluded.

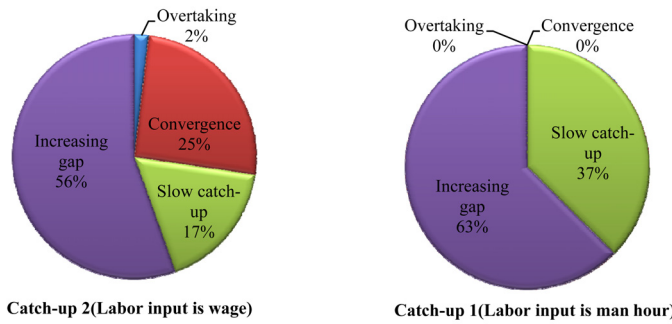


FIGURE 6
SHARES OF FOUR PATTERNS OF CATCH-UP 2
COMPARED WITH CATCH-UP 1

in 2001 but shrunk in 2004. The leading firm was Shanghai Zhenhua Port Machinery, which had a 10.6% share to the sales revenue of the industry.

(d) Pattern 4: "Reverse Catch-up"

Sectors in this pattern showed "negative" catch-up performance during the study period, indicating a rather increasing TFP gap. These industries are shown in the lower section of the XY space. As shown in Table 5 and Figure 5, industries that manifested this pattern were those involved in rubber and miscellaneous plastics, food and kindred products, primary metal, miscellaneous manufacturing, chemicals, stone clay glass, transportation equipment, and paper and allied. As shown in Table 6, the shares of those industries to the total number of firms and to the total amount of sales revenue of the Chinese manufacturing sector were 55.5% and 18.6%, respectively. An example of this sector is the chemical industry, which shrunk during the study period.

In summary, we may say that from 1999 to 2005, over 73% of firms still showed "slow catch-up" and "reverse catch-up" patterns, even though some firms manifested "overtaking" and "convergence." Therefore, the overall Chinese industry remained inferior compared with the overall Korean industry.

VII. Conclusion

In this paper, we calculated the TFP level of listed firms in China

using financial data from CSMAR. For TFP measurement, the key findings are as follows: First, China's TFP showed several increases, but remained relatively stagnant. Second, the TFP of IT-related industries, such as those in electronics, machinery, transportation, communication, and commercial, obviously increased, but the TFP of other industries remained low. Third, p25 and p75's quantile annual TFP gap widened. Fourth, one of the most important reasons for China's low productivity was that the TFP of big firms, which have the potential to drive the overall productivity of China, was low.

We used four patterns of the catch-up method (*i.e.*, overtaking, convergence, slow catch-up, and reverse catch-up) developed by Jung and Lee (2010) to classify the catch-up patterns that occurred between Chinese and Korean manufacturing industries. For this purpose, two labor inputs — man hour and wage — were adopted.

Using man hour as labor input produced the following results. First, no catch-up occurred in the overall industry level from 1999 to 2005. The TFP of listed Chinese manufacturing firms ranged from 60% to 80% of that of Korean firms. The average TFP level of listed Chinese manufacturing firms stood at only 28.1% of that of Korean firms by the end of 2005. Second, "slow catch-up" and "reverse catch-up" patterns manifested, indicating the very large gap between the overall industry TFP of the two countries.

The results from the second method, which used wage as labor input, are as follows. First, the TFP of Chinese manufacturing firms in 1999 was 30% lower than that of Korean manufacturing firms. The figure consistently decreased until it reached 20% by the end of 2005, indicating that the TFP gap narrowed. The average TFP level of Chinese listed manufacturing firms stood at only 71.5% of that of Korean firms by the end of 2005. Second, all of the four catch-up patterns occurred. The apparel industry showed an "overtaking" pattern. Four industries, namely, electrical machinery, textile mill products, instruments, and petroleum and coal products, showed a "convergence" pattern. Four industries, namely, printing, publishing, and allied, motor vehicles, fabricated metal, and non-electrical machinery, showed a "slow catch-up" pattern. Lastly, the remaining eight industries, namely, rubber and misc plastics, primary metal, miscellaneous manufacturing, chemicals, stone clay glass, transportation equipment, and paper and allied, showed a "reverse catch-up" pattern.

We found that no TFP catch-up between Chinese and Korean listed manufacturing firms occurred from 1999 to 2005. Moreover, the overall

TFP catch-up level depended on the different labor input methods, that is, the TFP catch-up level of Chinese manufacturing firms was very low when man hour was used as labor input, but was higher and approached that of Korean firms when wage was used as labor input.

(Received 25 April 2011; Revised 20 November 2011; Accepted 22 November 2011)

References

Aw, B., Chen, X., and Roberts, M. "Firm-level Evidence on Productivity Differentials, Turnover, and Exports in Taiwanese manufacturing." *Journal of Development Economics* 66 (No. 1 2001): 51-86.

Bak, C., Kim, Y., and Kwon, H. "Productivity Growth and Competition across the Asian Financial Crisis: Evidence from Korean Manufacturing Firms." Center Economic Institutions Working Paper Series No. 2009-12, Hitotsubashi University, 2009 (in Japanese).

Brandt, L., Van Biesebroeck, J., and Zhang, Y. Creative Accounting or Creative Destruction? Firm-Level Productivity Growth in Chinese Manufacturing. NBER Working Paper No. w15152, 2009.

Cao, J., Ho, M., Jorgenson, D., Ren, R., Sun, L., Yue, X., Center, L., and China, B. "Industrial and Aggregate Measures of Productivity Growth in China, 1982-2000." *Review of Income and Wealth* 55 (No. s1 2009): 485-513.

Cheng, Y. Regional Disparities of Industrial Productivity Growth in China. the ACESA2006 Conference on Emerging China: Internal Challenges and Global Implications, Victoria University, Melbourne, 13-14 July, 2006.

Cheng, Y.-S., and Lo, D. Firm Size, Technical Efficiency and Productivity Growth in Chinese Industry. School of Oriental and African Studies, Working Paper, London, UK, 2004.

Cheong, Y.-R., and Lee, J. K. The Risen of Chinese Economy and the Industry Policy of Korea. Finance Economy Research Vol. 161, Bank of Korea, 2003 (in Korean).

Fu, X., and Floor, T. Exports, Technical Progress, and Productivity Growth in Chinese Manufacturing Industries. ESRC Centre for Business Research, University of Cambridge, 2004.

Fu, X., and Gong, Y. "International and Intranational Technological Spillovers and Productivity Growth in China." *Asian Economic*

Papers 8 (No. 2 2009): 1-23.

Fukao, K., Inui, T., Ito, K., Kim, Y. G., and Yuan, T. An International Comparison of the TFP Levels of Japanese, Korean, Taiwanese, and Chinese Listed Firms. JCER Working Paper, pp. 91-120, 2009.

Good, D., Nadiri, M., and Sickles, R. Index Number and Factor Demand Approaches to the Estimation of Productivity. National Bureau of Economic Research, Cambridge, Mass., USA, 1996.

Gordon, R., and Li, W. "The Change in Productivity of Chinese State Enterprises, 1983-1987." *Journal of Productivity Analysis* 6 (No. 1 1995): 5-26.

Holz, C. "China's Statistical System in Transition: Challenges, Data Problems, and Institutional Innovations." *Review of Income and Wealth* 50 (No. 3 2004): 381-409.

Hsieh, C. T., and Klenow, P. J. "Misallocation and Manufacturing TFP in China and India." *Quarterly Journal of Economics* 124 (No. 4 2009): 1403-48.

Jefferson, G., Rawski, T., and Zheng, Y. "Chinese Industrial Productivity: Trends, Measurement Issues, and Recent Developments." *Journal of Comparative Economics* 23 (No. 2 1996): 146-80.

_____. "Productivity Growth and Convergence across China's Industrial Economy." *Journal of Chinese Economic & Business Studies* 6 (No. 2 2008): 121-40.

Jung, M., Lee, K., and Fukao, K. "Total Factor Productivity of the Korean Firms and Catching Up with the Japanese Firms." *Seoul Journal of Economics* 21 (No. 1 2008): 93-137.

Jung, M., and Lee, K. "Sectoral Systems of Innovation and Productivity Catch-up: Determinants of the Productivity Gap between the Korean and Japanese Firms." *Industrial and Corporate Change* 19 (No. 4 2010): 1037-69.

Kuan, C., Hongchang, W., Yuxin, Z., Jefferson, G., and Rawski, T. "Productivity Change in Chinese Industry: 1953-1985." *Journal of Comparative Economics* 12 (No. 4 1988): 570-91.

Li, Z., and Yu, M. Exports, Productivity, and Credit Constraints: A Firm-Level Empirical Investigation of China. China Center for Economic Research, Peking University, Working Paper Series, August 26, 2009.

Motohashi, K. Assessing Japan's Industrial Competitiveness by International Productivity Level Comparison with China, Korea, Taiwan, and United States. International Conference on Productivity and Efficiency, Academia Sinica Economic Institute, Taipei, June 20,

2005.

Ozyurt, S. "Total Factor Productivity Growth in Chinese Industry: 1952-2005." *Oxford Development Studies* 37 (No. 1 2009): 1-17.

Qiu, B., Yang, S., Xin, P., and Kirkulak, B. "FDI Technology Spillover and the Productivity Growth of China's Manufacturing Sector." *Frontiers of Economics in China* 4 (No. 2 2009): 209-27.

Rae, A., Ma, H., Huang, J., and Rozelle, S. "Livestock in China: Commodity-specific Total Factor Productivity Decomposition Using New Panel Data." *American Journal of Agricultural Economics* 88 (No. 3 2006): 680-718.

Ren, R., and Sun, L. Total Factor Productivity Growth in China Industries 1981-2000. International Comparison of Productivity among Asian Countries, (ICPA) Project, RIETI Database No. 5, Research Institute of Economy, Trade And Industry, Tokyo, Japan, 2006.

Schreyer, P. International Comparisons of Levels of Capital Input and Productivity. OECD/Ivie/BBVA Workshop on Productivity Measurement, Madrid, 17-19 October, 2005.

Wang, L., and Szirmai, A. "Productivity Growth and Structural Change in Chinese Manufacturing, 1980-2002." *Industrial and Corporate Change* 17 (No. 4 2008): 841-74.

Wu, H. X. "Measuring Productivity Performance by Industry in China, 1980-2005." *International Productivity Monitor* 15 (Fall 2007): 55-74.

Yu, M. Trade Liberalization, Firm Exits, and Productivity Evidence from Chinese Plans. China Center for Economic Research, Peking University Working Paper Series No. 6, 2008.

Yuan, T., Fukao, K., and Liu, D. Measurement of the Total Factor Productivity of Chinese Firms. JCER Working Paper, pp. 27-62, 2007 (in Japanese).

Zheng, J., and Hu, A. "An Empirical Analysis of Provincial Productivity in China (1979-2001)." *Journal of Chinese Economic and Business Studies* 4 (No. 3 2006): 221-39.

Zheng, J., Liu, X., and Bigsten, A. "Efficiency, Technical Progress, and Best Practice in Chinese State Enterprises (1980-1994)." *Journal of Comparative Economics* 31 (No. 1 2003): 134-52.

Zhou, X., and Han, C. Measures Technical Efficiency between China's Regions and Decomposes the Growth Rate of TFP (1990-2006). The Fifth Biennial Conference of Hong Kong Economic Association, Globalization and Economic Stability, Chengdu, China, 2008 (in Chinese).