Analyzing China's Provincial Total Factor Productivity and Its Influencing Factors

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Abstract: This paper decomposed the total factor productivity (TFP) into technological progress and efficiency change by deriving the Malmquist index through data envelopment analysis. Using the panel data of Chinese provinces from 1979 to 2007, this paper studied the TFP of each province, as well as the technological progress, the efficiency change, and their influencing factors.

The research results indicate a fluctuation in China's TFP during 1979 to 2007. Following an initial increase from negative to positive (1979-1991), the growth of China's TFP began to slow down from 1992 to 1996 and retained stable later on (1997-2004). A small fluctuation was observed from 2005 to 2007 with both technological progress and efficiency change starting to decline after a small peak.

The analysis reveals different TFP levels among the eastern region, western region and the central region. Such difference was not obvious from 1979 to 1989; however the gap enlarged from 1990 to 2007.

Among the influencing factors for technological progress and efficiency change, the proportion of population with tertiary education, R&D investment and the actual utilization of FDI have significant effects on the progress of technology; the industrial structure and government administration expenses have a significant impact on efficiency change. The difference in the constant terms of the model indicates that provincial features, such as infrastructure, government policies and human resource, are also influential.
Key Words: Total Factor Productivity; Technological Progress; Efficiency Change

1. INTRODUCTION

Since China's economic reform, the Chinese economy has been growing at a rate higher than most countries. Some scholars view such rapid growth as one with high input but low efficiency (Hu, 2002). Some consider this growth pattern as similar to the Southeast Asia: starting low, the growth is accompanied by large export volume, significant agricultural population, high domestic savings rate and investment rate (Sachs and Woo, 1997). Other scholars believe that the growth of Chinese economy can be explained by the improvement in efficiency, which can be measured by the total factor productivity (TFP) (Bhattasali, 2001). Given the disagreement in what caused China's rapid growth, it's important to give an accurate measure China's actual TFP level, as well as to analyze the interaction between the TFP and other influencing factors, in order to further study the source of China's economic growth.

Past studies of TFP have focused on the following aspects:

(1) TFP analysis of agricultural and industrial sectors (Lin,1992; Jefferson, 1996; Kong, 1999; Rae and Ma, 2003; Zhang, 2003). Shi (1986) estimated that the TFP of Chinese industry contributed 20% of the total output growth. Based on a study of 293 firms, Jefferson et al (1992) observed an increase in the TFP of post-reform state-owned enterprises, and an even higher increase in the TFP of collectively–owned enterprises. Chow (1993), on the other hand, found no trend of increasing TFP in Chinese industry. He claims that the growth of Chinese economy owes to increasing investment in factors of production instead of improving technology. Timmer (2003) studied the structural change in the industrial sectors of four Asian countries, and discovered a universal pattern of increased productivity. Young's (2003) research showed that the TFP growth of non-agricultural sectors during the 20 years after Chinese economic reform is only 1.4%, a number significantly lower than those in the previous studies. Based on nonparametric Malmquist index, Shen (2006) calculated the TFP of Chinese manufacturing industry from 1985 to 2003, and found the TFP growth depending mainly on the advance of technologies, while change in efficiency only had negative effects.

(2) Measurement of national and interprovincial TFP and study of the regional differences. Li (1996) found that the driving force of Chinese economy is capital investment (75%) and labor input (19.5%); the growth of TFP has relatively smaller influence (5.5%). Wang (2000) estimated the TFP growth to be -0.71% from 1953 to 1978 and 1.46% from 1979 to 1999, which contributes to 14.9% of the economic growth. Wang and Yao (2003) included human capital in their analysis and claimed that China's TFP has made negative contribution in the early years of the economic reform; however after the reform the TFP contributed 25.4% of the economic growth. Guo, Zhao and Jia (2005) analyzed provincial data from 1979 to 2003 and found deepening gaps among provincial economic growth, which could be mainly explained by differences in TFP. However, Wang (2006) observed constant gap in TFP across provinces based on panel data from 1978 to 2003, as well as a decreasing trend of TFP after 1990. Similar conclusions can also be found in other papers (Zheng and H, 2003; Li and Li, 2006; Shen, 2006).

(3) Analysis of TFP's influencing factors. Using provincial data from 1990 to 2004, Li and Li (2006) discovered that the decline in TFP is mainly caused by a decrease in per capita capital stock and R&D input; increasing dependence on international trade does not have significant influence on TFP growth. Romer (1990a, 1990b) and Mankiw, Romer and Weil (1992) viewed human capital stock as a main explanatory variable of technological progress or TFP. Based on Cobb-Douglas production function and data of capital stock, human capital stock and economic growth across countries, Benhabib and Spiegel (1994) concluded that the growth of TFP is mainly affected by human capital. Bemstem and Yan (1996) studied the relationship between R&D spillovers and productivity in Canada and Japan, and found the influence of domestic spillovers on TFP to be larger than international ones. Based on a study of R&D spillovers in Asia and OECD countries, Madden (2001) established an empirical model relating TFP to domestic and foreign R&D activities. Based on empirical studies in Italy, Atella (2001) believes the R&D can affect TFP. By investigating American buyer in developing countries, Egan and Mody (1992) found that in the long run, suppliers in developing countries benefited from the employee training offered by American entrepreneurs. Coe, Helpman (1993) and Coe, Helpman and Hoffmaister (1997) proved that the TFP of a country was not only dependent on domestic R&D input, but

was also influenced by international trading. The research of Edwards (1997) using data from 93 countries showed that relatively open economies have faster productivity growth. Gereffi (1999) studied the global commodity chain and found the TFP was highly dependent on foreign trade. Wei (2008) discovered a positive impact of human capital, infrastructure, urbanization, and agriculture proportion on TFP. Liu and Liu (2006) analyzed how foreign direct investment, industrial clusters, infrastructure, urbanization and institution reform influence TFP. Many more studies have focused on how the integrated factors affected TFP. (Wang and Chen, 2005; Yuan, Chen and Hu, 2005; Huang, 2006; Dai and Chen, 2007)

(4) The influence of technological innovation and efficiency on TFP. So far studies in this area are limited to qualitative analyses. (Zheng and Hu, 2004; Yue and Liu, 2006; Wang et al, 2006)

To summarize, with increasing studies on Chinese economic growth, more thorough researches on TFP have been carried out. However a few questions regarding TFP still need to be answered: how do we measure the contributions of technological progress and technical efficiency? How do we quantitatively analyze the influencing factors of TFP? Some scholars (Li and Li, 2006; Liu and Liu, 2006; Wei 2008) have analyzed the relationship between TFP and single factor (R&D, technical spillover, etc.), and tried to explain which factors pushed Chinese economic growth. However these studies still lack numerical analysis and cannot explain which factors lead to technological progress and technical efficiency. Therefore, detecting and quantitatively analyzing the influence factors of technological progress and efficiency change has become a key of TFP and economic growth analysis. Based on that, this paper will discuss the deterministic factors of technological progress and efficiency change, and explore the relationship between TFP and regional economic growth.

Note that since the 2008 financial crisis, the Chinese government has invested heavily in public goods in order to boost economic growth, which may lead to an unnatural variation of TFP. Due to this reason, this paper focuses on data from 1979 to 2007.

2. ESTIMATING CHINA'S PROVINCIAL TOTAL FACTOR PRODUCTIVITY

2.1 Malmquist index analysis and decomposition of total factor productivity

The Malmquist index based on data envelopment analysis (DEA) can decompose TFP into to technological progress, efficiency change, and scale efficiency on the basis of frontier production functions. Follow the definition of Färe (1994). we assume the input vector of *DMU*, the *i*th decision-making unit, at time t to be $X_i^t = (X_{i1}^t, X_{i2}^t, \dots, X_{im}^t)$, and its corresponding output to be Y^t. Total number of decision-making units is n, and a pair of input and output is denoted as (X^t, Y^t). $x^t \in R_+^N$, $y^t \in R_+^M$. We denote S^t as a set of all feasible production from input X^t to output Y^t:

$$S^t = \{(x^t, y^t) : x^t \ produces\ y^t\},\ t = 1, \dots, T \tag{2-1}$$

In S^t, the subset of maximum output for each given input is called the production technology frontier. The output distance function of DMU_0 in time period t can be defined as

$$D_o^t\left(x^t, y^t\right) = \inf\left\{\theta : \left(x^t, y^t/\theta\right) \in S^t\right\} = \left(\sup\left\{\theta : \left(x^t, \theta y^t\right) \in S^t\right\}\right)^{-1} \tag{2-2}$$

This distance function expresses the ratio of maximum potential output versus the actual output given the level of input. $D_o^t\left(x^t, y^t\right) \le 1$ if and only if $\left(x^t, y^t\right) \in S^t$. When $D_o^t\left(x^t, y^t\right) = 1$, $\left(x^t, y^t\right)$ is on the technology frontier, i.e. its technological efficiency is 1, and the output level given the input is maximized. In the case of single input and single output, maximum output is realized when the productivity is maximized. Therefore, a maximized productivity is the "frontier" and the "optimal choice" across all samples.

Now we use the technology at time t as reference to measure the output distance function at time t+1 with (X^t+1, Y^t+1):

$$D_o^t\left(x^{t+1}, y^{t+1}\right) = \inf\left\{\theta : \left(x^{t+1}, y^{t+1}/\theta\right) \in S^t\right\} \tag{2-3}$$

This distance function represents the ratio of maximum potential output versus actual output with at t + *1* given the technology at time *t*. Similarly we can calculate the ratio of maximum output versus actual output at t given the technology at time *t+1*. We denote it as $D_0^{t+1}(x^t, y^t)$.

The Malmquist index for TFP at time *t* can be expressed as

$$M_o^t = \frac{D_o^t\left(x^{t+1}, y^{t+1}\right)}{D_o^t\left(x^t, y^t\right)} \tag{2-4}$$

The Malmquist index for TFP at time *t+1* can be expressed as

$$M_o^{t+1} = \frac{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_o^{t+1}\left(x^t, y^t\right)} \tag{2-5}$$

To avoid confusion caused by different base years, we use the geometric mean of two Malmquist indexes from different time periods, and obtain

$$D\left(x^{t+1}, y^{t+1}, x^t, y^t\right) = \left[\left(\frac{D_o^t\left(x^{t+1}, y^{t+1}\right)}{D_o^t\left(x^t, y^t\right)}\right)\left(\frac{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_o^{t+1}\left(x^t, y^t\right)}\right)\right]^{1/2} \tag{2-6}$$

We assume constant returns to scale, i.e. technology is neutral. Then (2-6) can be further decomposed into two parts, technological progress and efficiency change.

$$\text{Efficiency change} = \frac{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}{D_o^t\left(x^t, y^t\right)} \qquad (2\text{-}7)$$

$$\text{Technological progress} = \left[\left(\frac{D_o^t\left(x^{t+1}, y^{t+1}\right)}{D_o^{t+1}\left(x^{t+1}, y^{t+1}\right)}\right)\left(\frac{D_o^t\left(x^t, y^t\right)}{D_o^{t+1}\left(x^t, y^t\right)}\right)\right]^{1/2} \qquad (2\text{-}8)$$

Efficiency change measures the change of output distance between time t and *t+1*; technological progress measures the ratio of technological progresses at different times given the same input and output level. If the efficiency change or technological progress is less than 1, it may lead to a decrease in the TFP.

We now use the provincial panel data to further illustrate the meaning of Malmquist index.

Suppose there exist $k = 1, \cdots, K$ provinces which use $n = 1, \cdots, N$ inputs at time $t = 1, \cdots, T$, denoted by $x_n^{k,t}$. The corresponding output is denoted by $y_m^{k,t}$, where $m = 1, \cdots, M$. The production technology frontier can thus be expressed as

$$S^t = (x^t, y^t) : y_m^t \leq \sum_{k=1}^{k} z^{k,t} y_m^{k,t} \quad \text{m=1,}\cdots\text{,M,}$$

$$\sum_{k=1}^{k} z^{k,t} x_n^{k,t} \leq x_n^t \quad \text{n=1,}\cdots\text{,N,} \qquad (2\text{-}9)$$

$$z^{k,t} \geq 0 \quad \text{k=1,}\cdots\text{,K,}$$

where z stands for the weight of each cross-section observation. For example, $z^{k,t}$ is the weight assigned to the observation from province *k* in time period t. Figure 2.1 illustrates the components of TFP, technological progress, and efficiency change.

X-axis represents input, Y-axis represents output. The two rays represent the production frontier S^t and S^{t+1}. $\left(x^t, y^t\right)$ is the observed input-output level at time t.

The distance is represented by *0a/0b*. The distance in *t+1* is represented by *0d/0c*. The ratio of productivity comparing *t+1* to *t* is therefore

$$T\dot{F}P^t = \frac{0d/0c}{0a/0b}, \qquad (2\text{-}10)$$

and similarly for *t+1*,

$$T\dot{F}P^{t+1} = \frac{0d/0f}{0a/0e}. \qquad (2\text{-}11)$$

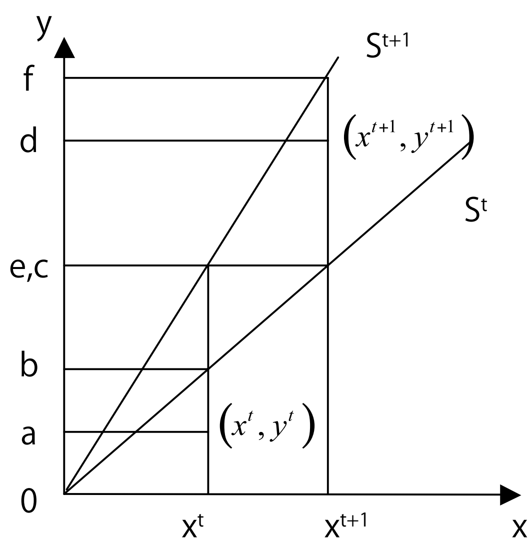

Fig 2.1 Malmquist index of TFP and decomposition

According to (2-6), the Malmquist index can also be illustrated by the vectors in fig.2.1.

$$M_o = \left(TFP^t \cdot TFP^{t+1}\right)^{1/2} = \left(\frac{0d/0c}{0a/0b}\frac{0d/0f}{0a/0e}\right)^{1/2} = \left(\frac{0d/0f}{0a/0b}\right)\left(\frac{0f}{0e}\frac{0c}{0b}\right)^{1/2} \quad (2\text{-}12)$$

efficiency change = $\frac{0d/0f}{0a/0b}$; technological progress = $\left(\frac{0f}{0e}\frac{0c}{0b}\right)^{1/2}$

The efficiency change can be further decomposed into pure efficiency change and scale effect if returns to scale is non-constant.

As Figure 2.2 shows, 0CG is the production frontier with constant returns to scale. BCD is the production frontier with non-constant returns to scale. Suppose E is an arbitrary point in the production possibility set, the efficiency change will be expressed by FE/FG with constant returns to scale. However, if the technology is not neutral, the efficiency change should be separated into two parts, pure effect change and scale effect. In the above figure they are expressed by FE/FD and DG. The scale effect is therefore defined as the ratio of the two efficiency changes (Forsund and Hjalmarsson,1979).

To summarize, the Malmquist index can be used to compare the efficiency change and technological progress in different time periods. Considering the scale effect, the Malmquist index can be decomposed as

$$Tfpch = Effch \times Techch = Pech \times Sech \times Techch \quad (2\text{-}13)$$

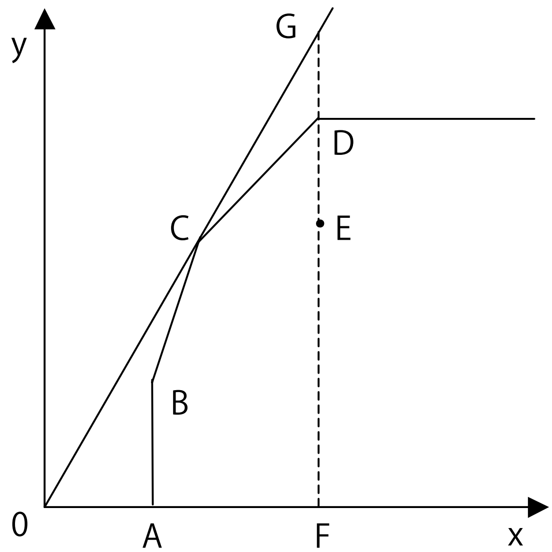

Fig 2.2 Pure Effect Change and Scale Effect

where Effch stands for efficiency change, and represents how close the given observations approach the production frontier. This index being greater than 1 indicates an increase in efficiency. Techch represents technological change; this number being larger than 1 indicates technological progress in given observations. Effch can be further expressed by the product of Pech and Sech, which stands for pure efficiency change and scale effect respectively.

2.2 Data source and variable definition

The provincial TFP calculation is based on provincial GDP, labor and capital stock. In this paper we use data from years 1978 to 2007. Provincial real GDP are deflated with 1978 as the base year. The data of earlier years come from *Comprehensive Statistical Data and Materials on 50 Years of New China 1949-1999* (NBS of China, 1999). The data of later years (1995-2007) come from China's statistical year books. Note that a large portion of data in Tibet and Hainan province were missing, therefore we omitted these two provinces from our observations. Since Chongqing was part of Sichuan province and did not become an independent province until 1997, for consistency we combine the data of Sichuan and Chongqing after 1997 into one observation. The total number of observations is 28.

The calculation of stock capital follows a perpetual inventory method with 1978 as the base year. For example the capital stock in 1979 equals the amount of fixed investment in this year multiplied by investment price index, then plus depreciated capital stock from 1978. Here we take depreciation ratio to be 9.6% (Jun Zhang, 2006). Labor stock in this paper is represented by the number of employees (Jinxu Cai, 2000; Yumin Ye, 2002).

2.3 Trend of China's TFP

According to the fluctuation, trend and composition of TFP, we divide the evolution of China's TFP from 1979 to 2007 into the following periods.

From 1979 to 1991, the TFP fluctuated largely with an increasing absolute value. This is mainly caused by efficiency change (average = 2%). The technological progress was negative in 1978 since at that time China was in the transaction from planned economy to market economy, and the allocation of resources can not meet the need of the new institution. Since 1989, technological progress becomes the major contributing factor instead of efficiency change. As we can see from Figure 2.3, the technological progress curve is above the efficiency change curve from 1989. Two factors lead to this change. First, during the late 1980s the Chinese government adopted a series of policies promoting the commercial application of technological innovations. Second, the price reform in 1988 resulted in small fluctuations in economic growth. The TFP thus exhibited a small decrease, followed by rapid rise with constant 4% increase rate.

From 1992 to 1996, we observe a decreasing TFP, which is largely affected by slower technological progress. One reason may be that China's investment in scientific and technological research declined during this time period; it may also result from a slow adoption of foreign technology. For example, the growth of China's Three Types of Expenditure in Science and Technology reduced from 30% in 1990 to 13.13% in 1992. From 1994 to 1995, the growth of the Three Types of Expenditure became negative (-14.92%). From 1993 to 1996, the growth of foreign investment also slowed down: the growth was 152.46% during 1990 to 1992, while it was only 16.95% from 1993 to 1996. Meanwhile, at this time period China experienced overcapacity and inflation. The domestic market transited from shortage to surplus.

During 1997 to 2004, the TFP stabilized with slowed down technological progress decline. The most evident characteristic of this period is the significant impact of technological progress on TFP growth. This indicates that with the institutional reform, the allocation of resources began to adapt to the market demands. The technological progress through innovation and imitating foreign technology began to have a larger impact in TFP than efficiency change. Scale benefit was far smaller than that in 1980s. The decreasing efficiency change also indicates a larger gap between actual output level and the production frontier.

During 2005 to 2007, The TFP displayed slight fluctuations. Both decline in technological progress and efficiency change are observed. Further investigation is needed to conclude whether such trend will retain.

2.4 Comparative study of provincial TFP

The data pool includes GDP, labor force and capital stock of 28 provinces in the past 30 years. We will use our analysis results of provincial TFP and its components to compare over time and across regions.

Table 2.2 lists the provincial TFP and its decomposition. The average provincial TFP during 1978-2007 is 1.022, which shows in this time period the regional economies progressed in scale efficiency, efficiency of productive factor usage, and technological progress. The TFP growth was largely driven by technological progress, which is inconsistent with Wu's (2002) findings that it is the efficiency change but not technological progress that promoted the Chinese TFP growth.

Table2.1 China's TFP change and its components (1979 - 2007)

Year	Efficicency Change	Technological progress	Pure Efficiency Change	Scale Effect	TFP Change
1979	1.0180	1.0040	1.0240	0.9940	1.0220
1980	1.0210	1.0090	1.0200	1.0010	1.0300
1981	1.0390	0.9710	1.0200	1.0190	1.0080
1982	1.0740	0.9680	1.0550	1.0190	1.0400
1983	1.0670	0.9750	1.0490	1.0180	1.0410
1984	1.0690	1.0020	1.0310	1.0370	1.0710
1985	1.0240	1.0090	0.9980	1.0260	1.0330
1986	1.0410	0.9450	1.0240	1.0160	0.9840
1987	1.0460	0.9700	1.0320	1.0130	1.0140
1988	1.0250	1.0020	1.0040	1.0210	1.0270
1989	0.9930	0.9930	0.9960	0.9980	0.9860
1990	0.9780	1.0180	0.9860	0.9910	0.9960
1991	0.9580	1.0670	0.9760	0.9820	1.0230
1992	0.9670	1.0990	0.9680	0.9990	1.0620
1993	0.9720	1.0800	0.9700	1.0020	1.0500
1994	0.9780	1.0550	0.9790	0.9990	1.0330
1995	1.0030	1.0230	1.0000	1.0040	1.0260
1996	1.0200	1.0070	1.0050	1.0150	1.0270
1997	1.0020	1.0220	1.0080	0.9940	1.0240
1998	1.0120	1.0020	1.0100	1.0020	1.0140
1999	0.9990	1.0160	0.9960	1.0030	1.0150
2000	0.9990	1.0120	1.0010	0.9980	1.0110
2001	0.9920	1.0170	1.0000	0.9920	1.0090
2002	0.9850	1.0260	0.9890	0.9950	1.0100
2003	0.9820	1.0300	0.9890	0.9930	1.0120
2004	0.9790	1.0320	0.9970	0.9820	1.0110
2005	1.0100	1.0100	1.0100	1.0000	1.0200
2006	1.0400	1.0590	1.0150	1.0250	1.1020
2007	1.0200	1.0030	0.9740	0.9680	1.0170

Among all the provinces, Shanghai and Guangdong have the highest TFP (4.3% and 4.5% respectively). However, the sources of TFP increase in these two provinces are different. Shanghai's TFP is largely influenced by technological progress while Guangdong's TFP was mainly affected by efficiency change. In Shanghai, the effects of industrial clusters as well as increasing FDI and skilled workers promoted the technological progress. In Guangdong technology and efficiency was improved through imitation and learning

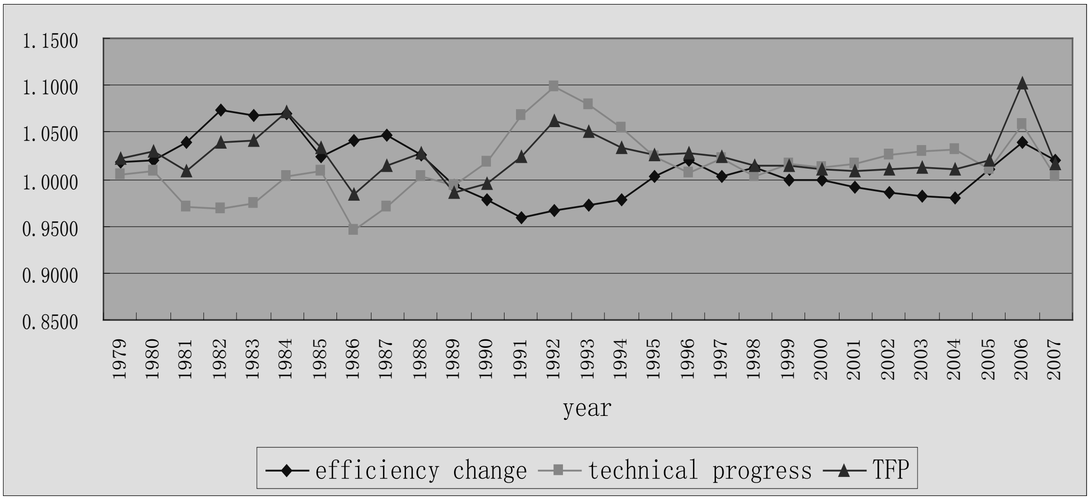

Fig2.3 TFP and its components over time

In the paper we also calculated the TFP and its components of eastern China, central China and western China. As shown in figure 2.4, before 1990 all three regions share similar rate of TFP. The eastern region has the fastest TFP growth afterwards. The main reason for this phenomenon is that during the earlier years of economic reform, the differences of technology and policies was not yet obvious across regions, while later on the eastern region became more open and attracted more economic resources. Therefore this region displayed a most significant improvement in technology and production efficiency.

With regard to the efficiency change, the efficiency change indexes were increasing in all regions from 1981 to 1985 (Figure 2.5). The average efficiency change was approximately 6%. The western region enjoyed a larger catch-up growth and it's been approaching the eastern region since 1990. Before 1990, efficiency change was mainly attributed to effect of institution. Since the institution reform and economic policies were universal and indifferent across China, there were no significant differences in efficiency among regions. From 1990, the eastern region is more open and attracts more economic resources and technology. As a result it has a higher efficiency index curve which surpasses the western and the central until 1995. Later on, the efficiency growth of the latter two regions accelerated with a faster speed that overtook the eastern region. As discussed before, the efficiency change can be divided into pure efficiency change and scale effect. The western and central regions benefited from the scale effect by expanding its production capacity; the eastern region, on the other hand, faced a decreasing scale effect.

Concerning the technological progress, all three regions displayed a similar pattern. From figure 2.6 we see that during 1979 to 1993, the three technological progress curves converge with average growth equals 3% to 4%. In the early years of the economic reform, the difference in regional development mainly resulted from scale economy effect rather than technological progress. In 1994, China's reform involved in various areas including finance, foreign trade, state owned enterprises, social security, etc. The power and influence of such reform in the eastern region is different from that in the west and the central. Meanwhile, the optimization of industrial structure, adoption of advanced technology, and the update of products were faster in the eastern region than the west and the central.

Table 2.2 TFP change and its components across provinces

Province	Efficiency Change	Technological progress	Pure Efficiency Change	Scale Effect	TFP Change
Beijing	0.991	1.038	0.987	1.004	1.029
Tianjin	1.021	1.009	1.013	1.007	1.029
Hebei	1.007	1.016	0.992	1.015	1.024
Shanxi	1.022	1.006	1.027	0.995	1.028
Neimengu	1.004	1.021	0.995	1.009	1.025
Liaoning	1.016	1.024	0.995	1.022	1.041
Jilin	1.011	1.008	1.012	1.000	1.020
Heilongjiang	0.996	1.016	0.997	0.999	1.012
Shanghai	1.000	1.043	1.000	1.000	1.043
Jiangsu	0.992	1.015	1.003	0.989	1.007
Zhejiang	1.007	1.020	1.009	0.998	1.027
Anhui	1.000	1.001	0.998	1.002	1.001
Fujian	1.016	1.005	1.005	1.011	1.021
Jiangxi	1.002	1.008	1.002	1.000	1.01
Shandong	1.008	1.011	0.998	1.01	1.019
Henan	1.011	1.003	0.999	1.012	1.014
Hubei	1.009	1.011	1.004	1.005	1.021
Hunan	1.012	1.001	1.016	0.997	1.014
Guangdong	1.029	1.015	1.014	1.015	1.045
Guangxi	1.014	1.001	1.016	0.998	1.015
Sichuan	1.011	1.019	0.989	1.022	1.031
Guizhou	1.011	1.001	1.013	0.998	1.013
Yunnan	1.027	1.003	1.032	0.995	1.030
Shanxi	1.008	1.01	1.009	0.999	1.018
Gansu	1.022	1.005	1.028	0.994	1.028
Qinhai	0.993	1.017	1.000	0.993	1.011
Ningxia	1.010	1.02	1.000	1.010	1.030
Xinjiang	0.999	1.011	0.982	1.018	1.01
Mean	1.009	1.013	1.005	1.004	1.022

3. AN ANALYSIS ON THE INFLUENCING FACTORS OF PROVINCIAL TFP

3.1 Influencing factors of efficiency change and technological progress

There are many factors that would influence technological progress. However, in the case of China, the main factors are investment in science and technology, spillover effect of foreign technology, stock of human capital and the investment in education. In this paper we choose 7 variables to represent the above aspects: percentages of people who receive primary, secondary and tertiary education as their highest level of education, three types of expenditure in science and technology, employment rate, total import and export volume, and the actual utilization of foreign investment (Table 3.1).

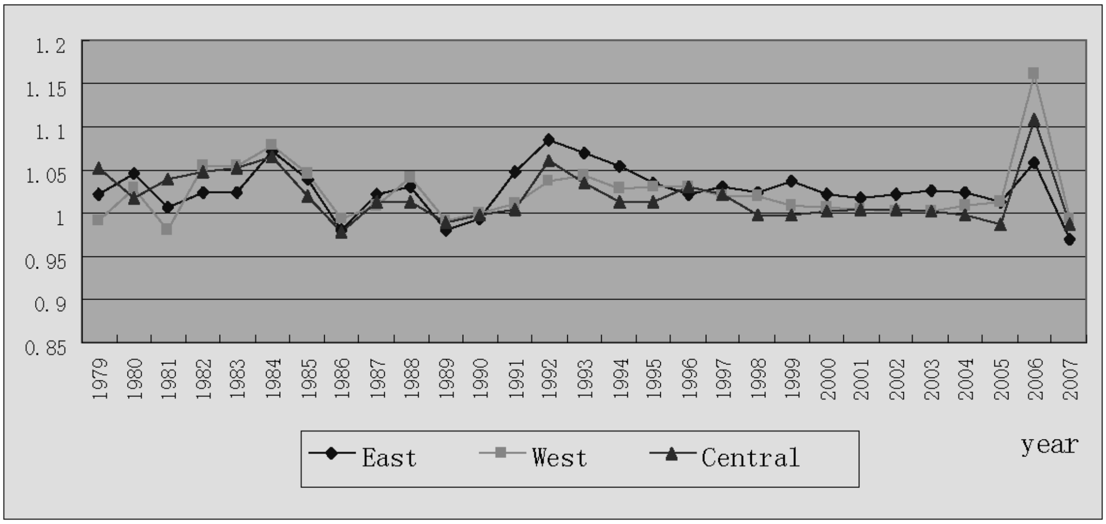

Fig2.4 Regional Comparison on TFP

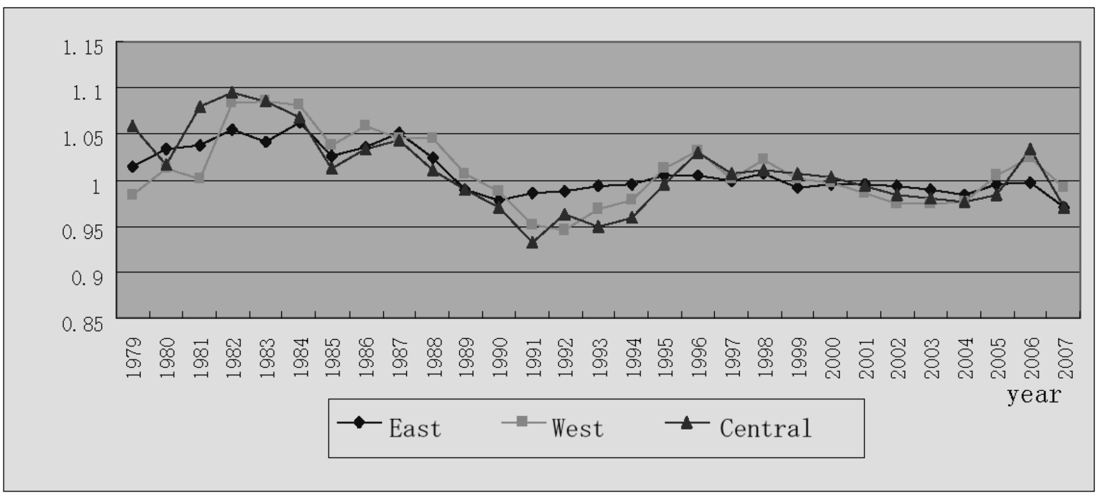

Fig2.5 Regional comparison on efficiency change

There are also numerous influencing factors for the improvement of a country's efficiency. In this paper the variables we are interested in are industrial structure, wage rate, investment in infrastructure, percentage of government's administrative expenses and the level of industrial agglomeration (Table 3.1).

Variable definition:

Level of industrial agglomeration = gross output of secondary sector in the given province / gross output of secondary sector in the whole country;

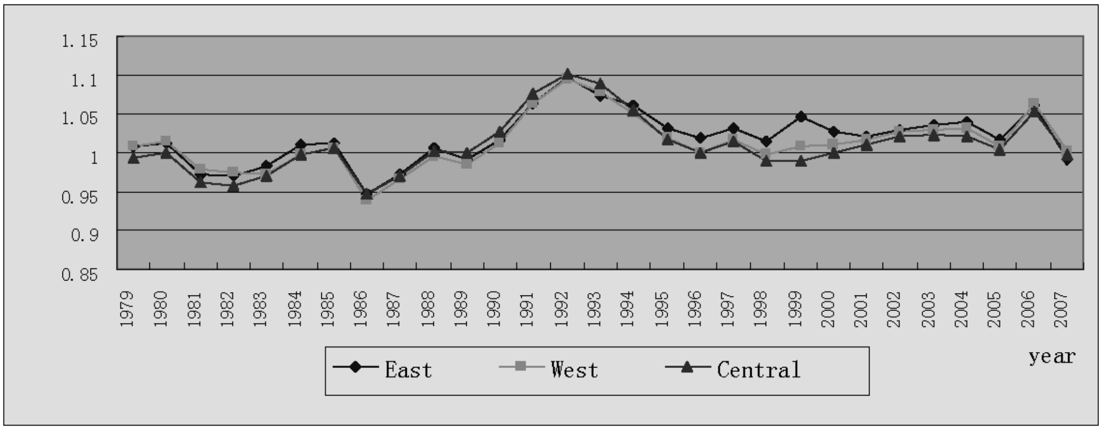

Fig2.6 Regional comparison on technological progress

Actual utilization of FDI = foreign investment utilized / total foreign investment;
Volume of import and export: converted into RMB using annual average exchange rates;
Employment rate = number of employed people / total population;
Education: primary education = 6 years, secondary = 9 years, tertiary education = 16 years; data come from survey of population above the age of 6;
Wage rate = average wage rate of employed population in given province;
Investment in infrastructure = the amount of expenses in infrastructure out of total fiscal expenditure;
Three types of expenditure in science and technology: government project funds supporting the trial manufacture of new products, intermediate experiments and major scientific projects. These expenses account for a large portion in total R&D expenditure;
Percentage of government administrative expenses = government administrative expenses / GDP; this ratio can be used as an indicator of the transaction cost of promoting production;
Structure of industry = growth of second and third sectors / growth of the first sector.

3.2 Data source

Most provincial data come from *China Statistical Yearbook, Comprehensive Statistical Data and Materials on 50 Years of New China 1949-1999* and *Data of Gross Domestic Product of China 1952-2004* with exceptions otherwise noted. We choose data from 1990 to 2007 for the following reasons. First, during the period of 1978 to 1990, a large portion of data is missing. Second, from the previous analysis we know that China's total factor productivity dropped for the first time in early 1990s. Therefore we should regard this turning point as a crucial part of our analysis. Third, in the early 1990s China was experiencing an acceleration of transition to market economy. Using 1990 as the starting point will enable us to capture the change of the above variables during this time period.

Table 3.1 Variable Descriptions

Variable	Description		Variable	Description
effch	Efficiency change		techch	Technological progress
Industru	Structure of industry		eduuni	Percentage of tertiary education
Wages	Wage rate		edumid	Percentage of secondary education
Infrastru	Investment in infrastructure		edupriv	Percentage of primary education
Governan	Percentage of government's administrative expenses		R&D	Three types of expenditure in science and technology
Induagglo	Level of industrial agglomeration		employ	Employment rate
			imexpor	Volume of import and export
			FDI	Actual utilization of FDI

3.3 Model of influencing factors of TFP and its applications

As mentioned above, in this paper we study 5 variables that affect the efficiency change and 7 variables that affect the technology progress. On this basis we establish the following model:

$$Effch_{it} = a_0 + \sum_{m=1}^{m} a_m x_{mit} + \varepsilon_{it} \qquad (3\text{-}1)$$

$$Techch_{it} = b_0 + \sum_{m=1}^{k} b_m y_{mit} + \varepsilon_{it} \qquad (3\text{-}2)$$

For province i at time t, the x's are industru, wages, infrastru, governan and induagglo and the y's are eduuni,edumid,edupriv,R&D,employ,imexpor and FDI.

3.3.1 Model testing

(1) ADF unit root testing

In order to avoid spurious regression problems, this paper uses ADF unit root testing method for the stationary test of the dependent and independent variables.

From table 3.2 we see that after adjustment for time lags (number of lags are indicated in the parentheses), the absolute values of the ADF test results for all variables are greater than the absolute values of the 1% confidence interval, which means all the variables are stationary. We selected the optimal number of lags by minimizing the AIC and Schwarz number, i.e., the parameter p that minimizes the AIC and SC values is taken as the optimal number of lags. Taking the variable "Wages" as an example:

Table 3.2 ADF Unit Root Test

Variables	ADF values	5% confidence interval	1% confidence interval	stationarity
Effch	-4.990792(2)	-2.867889	-3.444991	Stationary
Industru	-3.719052(6)	-1.941543	-2.570216	Stationary
Wages	-4.753017(7)	-3.420068	-3.979052	Stationary
Infrastru	-5.082083(4)	-2.867845	-3.44489	Stationary
Governan	-10.63252(2)	-2.867815	-3.444823	Stationary
Induagglo	-2.713746(4)	-1.94154	-2.570192	Stationary
Techch	-3.566482(4)	-2.867845	-3.44489	Stationary
Eduuni	-2.757941(4)	-1.94154	-2.570192	Stationary
Edumid	-6.144001 (12)	-2.867859	-3.444923	Stationary
Edupri	-7.617533(5)	-2.867965	-3.445162	Stationary
Imexpor	-4.415409(7)	-1.941545	-2.570228	Stationary
Employ	-10.16096(13)	-2.867995	-3.445232	Stationary
R&D	-2.585362(7)	-1.941545	-2.570228	Stationary
FDI	-4.00084(5)	-1.94154	-2.5702	Stationary

Table 3.3 Choice of lags for "Wages"

Lag	Akaike info criterion	Schwarz criterion
1	18.87242	18.90920
2	18.86760	18.91365
3	18.86904	18.92439
4	18.85546	18.92014
5	18.86067	18.93472
6	18.84846	18.93191
7	18.70236	18.79524
8	18.70855	18.81089

From the table 3.3 we can see the AIC and Schwarz values are minimized when number of lags equals seven. Therefore we choose seven as the optimal number.

Table 3.4 Granger Causality Test on Technological progress

Null Hypothesis	F-statistic	Probability
Eduuni does not Granger Cause Techch (4)	6.17635	7.7E-05*
Techch does not Granger Cause Eduunie (4)	1.42768	0.22381
Eximport does not Granger Cause Techch (7)	6.54835	2.3E-07*
Techch does not Granger Cause Eximport (7)	1.60870	0.13098
FDI does not Granger Cause Techch (5)	16.1569	13E-14*
Techch does not Granger Cause FDI (5)	2.74799	0.011856
Employ does not Granger Cause Techch (13)	7.70896	9.8E-14*
Techch does not Granger Cause Employ (13)	10.7318	9.8E-20*
R&D does not Granger Cause Techch (7)	3.25307	0.00224*
Techch does not Granger Cause R&D (7)	1.01338	0.42097
Edupri does not Granger Cause Techch (5)	4.29060	0.00081*
Techch does not Granger Cause Edupri (5)	1.04564	0.39023
Edumid does not Granger Cause Techch (12)	1.76808	0.11810
Techch does not Granger Cause Edumid (12)	10.9565	6.1E-10*

(2) Granger causality test

Since the variables are stationary, we can use granger causality test to test for the causal relationship between total factor productivity and the variables.

We use the same method above to determine the number of lags. Table 3.4 shows that under 1% significance level there is a causal relationship between technological progress and 6 variables: percentage of population with tertiary education, percentage of population with primary education, total import and export, foreign direct investment, employment rate and R&D. Among these variables, the employment rate and technological progress interlinked with each another, indicating that the employment rate can stimulate the technological progress while vice versa.

Using similar method we run the same causality test on efficiency change and relevant variables:

3.3.2 Economic meaning of the model

In this paper we use a fixed effects model to analyze our panel data, and the results are as follow.

3.3.2.1 Analysis of technological progress

In the fixed effects model with the technological progress as the dependent variable, the R-squared reaches 0.990608, indicating a high fitness of the model. The DW test statistic indicates that we can not rule out the possibilities of residual autocorrelation. However, since the cross section of the panel data is often large, often we only have the time demeaned error estimates, and the DW statistic is unlikely the error in the original model.

Table 3.5 Granger Causality Test on Efficiency Change

Null Hypothesis	F-statistic	Probability
Industru does not Granger Cause effch (6)	3.64921	0.01271
Effch does not Granger Cause Industru (6)	0.23939	0.86887
Wages does not Granger Cause Effch (7)	1.42655	0.16578
Effch does not Granger Cause Wages (7)	0.76552	0.66218
Infrastru does not Granger Cause Effch (4)	5.38137	0.00941*
Effch does not Granger Cause Infrastru (4)	2.74799	0.99563
Governan does not Granger Cause Effch (13)	2.21178	0.00214*
Effch does not Granger Cause Governan (13)	0.55205	0.94257*
Induagglo does not Granger Cause Effch (4)	2.21725	0.00208*
Effch does not Granger Cause Induagglo (4)	2.44197	0.00058*

(1) Education and technological progress.

Our results show a negative relationship between the technological progress and the percentage of population with primary (coefficient -0.1123) and secondary (coefficient -0.1174) education as their highest level of education, which is opposite to Phelps's views. However in the case of China, since the implementation of compulsory education, the attendance rate of primary school has reached 99.54% in 2008, which means primary and even secondary education has been carried out universally. Therefore a further widespread of primary and secondary education is not enough to motivate technological innovation; it is the level of tertiary education that most promotes technological progress. From the results above we indeed see a positive relation between tertiary education and technological progress.

(2) Investment in R&D and technological progress.

It can be intuitive that investment in R&D has a positive relation with technological progress. The former directly motivates new products and technology. In our model the estimated coefficient for R&D is 0.00325, a positive but rather small number. This may be explained by the fact that we only use the three types of expenses in science and technology as an indicator of R&D investment, and we have not include information on the investment in R&D from private companies or organizations. However we cannot exclude the possibility that the influence of R&D investment in indeed low in China; for example there may be inefficiency in the actual usage of the government funds.

(3) Employment rate and technological progress.

The influence of employment rate on technology progress is negative but insignificant. Since Chinese industries are still labor intensive, employment rate does not have a significant relationship with technological progress.

Table 3.6 Influencing factors of technological progress

Variable	coefficient	standard deviation	P-value
C	1.17062	0.026254	0
EDUUNI?	0.087454	0.083112	0.0433
EDUMID?	-0.117412	0.023132	0
EDUPRIV?	-0.112344	0.042357	0.0083
R&D	0.00325	1.22E-09	0.0082
EMPLOY?	-0.079601	0.04202	0.0589
IMEXPOR?	4.66E-10	8.70E-10	0.0926
FDI?	-7.10E-08	5.94E-08	0.0124
Fixed Effects (Cross)			
BJ_--C	0.049987		
TJ_--C	0.001419		
HEB_--C	0.016108		
SX_--C	-0.010781		
NM_--C	0.007917		
LN_--C	0.004511		
JL_--C	-0.004709		
HL_--C	0.008975		
SH_--C	0.035909		
JS_--C	0.020376		
ZJ_--C	0.025143		
AH_--C	-0.02428		
FJ_--C	-0.00577		
JX_--C	-0.009886		
SD_--C	0.010197		
HN_--C	-0.013794		
HB_--C	-0.005591		
HUN_--C	-0.015081		
GD_--C	0.037018		
GX_--C	-0.016065		
SC_--C	0.010815		
GZ_--C	-0.030582		
YN_--C	-0.029373		
SHX_--C	-0.007374		
GS_--C	-0.021149		
QH_--C	-0.023733		
NX_--C	-0.003351		
XJ_--C	-0.006856		
Effects Specification			
Cross-section fixed (dummy variables)			

Weighted Statistics			
R-squared	0.990608	Mean dependent var	1.171319
Adjusted R-squared	0.989835	S.D. dependent var	0.324661
S.E. of regression	0.032732	Sum squared resid	0.442492
F-statistic	1281.257	Durbin-Watson stat	0.867092
Prob(F-statistic)	0		
Unweighted Statistics			
R-squared	0.262092	Mean dependent var	1.032525
Sum squared resid	0.445094	Durbin-Watson stat	0.855645

(4) Import-export volume and technological progress.

Import-export volume has a significant positive relationship with technological progress. This indicates that foreign technology spillover and the imitation of foreign technology has positively influenced China's technological progress. The competition in the global market pushes the production frontier forward and optimized the scale of Chinese enterprises. However, though being positive, the coefficient is quite small (4.66E-10). From the perspective of import, though the import of hi-tech products has created the chance of imitating foreign technology, most of the imports are the semi-finished materials to be used on the exported goods (Bing Hu and Jing, Qiao, 2008) which do not have much potential for the learning of technology. From the perspective of export, although the quality and structure of the exported goods have been greatly improved during recent years, China's exported good still cannot compete with other countries in terms of quality and added-value and it doesn't play an important part in stimulating the progress of technology (Yuan Shu, 1998). Therefore we can conclude that the influence of import and export volume on technological progress is still limited.

(5) Actual utilization of FDI and the technological progress.

FDI has a small negative influence on technological progress according to our results. FDI not only brings funds but also brings advanced technology and management methods. As Changyuan Luo (2006) found out, FDI creates better conditions for the growth of TFP. In general, there is a time lag between the introduction of foreign technology and its full absorption which is partly dependent on local features such as local technology and human resource. If the local features are unfavorable, the cost of learning and absorbing time will correspondingly increase.

(6) Provincial features.

Beijing, Shanghai and Guangdong have the largest constant term among the 28 provinces; the constant term for western provinces such as Guizhou and Gansu are relatively smaller. This indicates a relationship between regional features and technological progress. Eastern provinces have advantages in infrastructure, policies and human capital stock which lead to a larger technological progress. Western provinces are still restricted by regional features though they have a fast catch-up growth.

3.3.2.2 Analysis of efficiency change

Table 3.7 Influencing factors of Efficiency Change

Variable	Coefficient	Standard Deviation	P-value
INDUSTRU?	0.000246	0.000171	0.0028
WAGES?	6.18E-07	3.01E-07	0.0409
INFRASTRU?	4.72E-10	4.48E-09	0.0162
GOVERNAN?	-0.171612	0.042883	0.0001
INDUAGGLO?	0.130705	0.164362	0.4269
Fixed Effects (Cross)			
BJ_--C	0.005104		
TJ_--C	0.030667		
HEB_--C	-0.004132		
SX_--C	0.010497		
NM_--C	-0.020794		
LN_--C	0.030333		
JL_--C	-0.004317		
HL_--C	-0.005044		
SH_--C	0.031501		
JS_--C	-0.00777		
ZJ_--C	-0.011553		
AH_--C	-0.020037		
FJ_--C	-0.000594		
JX_--C	-0.014848		
SD_--C	0.008947		
HN_--C	-0.00342		
HB_--C	-0.014656		
HUN_--C	0.00234		
GD_--C	0.021231		
GX_--C	-3.28E-05		
SC_--C	0.020719		
GZ_--C	-0.012576		
YN_--C	0.009219		
SHX_--C	-0.009209		
GS_--C	0.003012		
QH_--C	-0.021502		
NX_--C	-0.002714		
XJ_--C	-0.020372		
Effects Specification			
Cross-section fixed (dummy variables)			
Weighted Statistics			

R-squared	0.999391	Mean dependent var	2.102665
Adjusted R-squared	0.999344	S.D. dependent var	1.685321
S.E. of regression	0.043153	Sum squared resid	0.772809
F-statistic	21292.87	Durbin-Watson stat	1.134434
Prob(F-statistic)	0		
Unweighted Statistics			
R-squared	0.082396	Mean dependent var	0.990507
Sum squared resid	0.869232	Durbin-Watson stat	1.154326

We estimate a fixed effects model of the efficiency change, and the results are shown in table 3.7. The R-squared for our model is 0.999391, indicating a high fitness of the model.

(1) Industry structure and efficiency change.

The industry structure is measured by the ratio of added-value in second and third sectors to the added-value in the first sector. It has a positive influence on efficiency change (0.000246).

(2) Wage rate and efficiency change.

The influence of wage rate on efficiency change is not significant as it has not passed the 5% significance level.

(3) Investment in infrastructure and efficiency change.

Investment in infrastructure has a positive relationship with efficiency change. To some extent it gives the less developed provinces an opportunity to catch up with the developed provinces through investment in infrastructure. According to the study of Dina Jiang (2003), the TFP of railway transportation industry is rising with significant scale effect. Driven by fixed investment after the 90s, the development of road transportation improves the efficiency of less developed area, especially the western region. Affected by the growth of fixed investment, civil aviation industry has scale effect, and its development boosts the economic efficiency of developed provinces.

(4) Government administrative expenses and efficiency change.

Government's administrative expenses have a significant negative effect on efficiency change. On the one hand, the intervention of government may reduce the efficiency of capital and labor input; on the other hand, higher administrative expenses in proportion to other expenses also indicate that the cost of governance has a low efficiency in driving the economy.

(5) Industrial agglomeration and efficiency change.

Industrial agglomeration can reduce the transaction costs among enterprises and improve efficiency through positive externalities. In accordance with this theory, our model displayed a positive relationship between industrial agglomeration and efficiency change.

4. CONCLUSION

The development of China's TFP from 1979 to 2007 can be separated into the following time periods: From 1979 to 1991, following a rapid growth in Chinese economy, the TFP increased from negative to positive. From 1992 to 1996, while the speed of economic growth was still high, the growth of the TFP began to slow down. From 1997 to 2004, with high economic growth, the growth of TFP tended to be stable, despite a decline in technological progress. During 2005 to 2007 there was a small fluctuation in the TFP; both technological progress and efficiency change started to decline after a small peak. However since we do not have further data, the observations in these three years are not enough for us to draw any conclusion on future TFP trend.

The analysis in this paper also reveals different TFP levels among the eastern region, western region and the central region. Such difference was not obvious from 1979 to 1989; however the gap enlarged from 1990 to 2007. This can be explained by the fact that China's economic reform has a larger impact in the eastern region; fast industrial development, increasing foreign trade and foreign investment enabled the firms in the eastern region to obtain new technology and learn new techniques, which in turn resulted in a larger technological progress compared with the west and the central.

In the paper we also studied the influencing factors for technological progress and efficiency change. Among the relevant variables, the proportion of population with tertiary education, R&D investment and the actual utilization of FDI have significant effect on the progress of technology; the industrial structure and government administration expenses have a significant influence on efficiency change. The difference in the constant terms of the model indicates that provincial features, such as infrastructure, government policies and human resource, also affect technological progress or efficiency change.

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