Calculation of Total Factor Productivity and Potential Growth Rate

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Abstract

In recent years, China's economy has gradually shifted from the phase of high-speed growth to medium-speed and high-quality growth. Instead of blindly pursuing high-speed growth in the past, China has focused on total factor productivity (TFP) to promote the reform of quality, efficiency and power of economic development. In this context, it is of great theoretical and practical significance to accurately estimate China's total factor productivity and potential growth rate. Based on the calculation of capital stock and labor input, this paper employs the production function method and data envelopment analysis to calculate the annual TFP growth rate of all industries from 1979 to 2018, the quarterly TFP growth rate of all industries from 2006 to 2018, and the annual TFP growth rate of 19 major industries from 2006 to 2018 respectively. Meanwhile, by predicting the growth rate of capital stock, the growth rate of employment and the growth rate of TFP in the next five years, the production function method is adopted to forecast the potential growth rate in the next five years.

The study finds that, first, from the perspective of the annual data of all industries, since 1978, China's TFP growth has experienced three peaks in 1984, 1992 and 2007 respectively, and the TFP growth rate has been stabilized at around 3% in the recent five years. Second, in terms of the quarterly data of all industries, after the financial crisis, China's TFP growth rate dropped sharply, and continued to fluctuate and decline after a certain rebound. Around 2016, an inflection point from decline to rise occurred. Third, with regard to of the tertiary industry, the TFP of the tertiary industry has the highest annual growth rate since 2006, followed by the secondary industry, and the TFP of the primary industry basically shows negative growth. Fourth, from the perspective of sub-sectors, during the entire sample period from 2006 to 2018, the TFP growth rate of different industries is significantly different, and the TFP growth rate in the production service industry is relatively fast. Fifth, the potential growth rate is expected to present a slight decline in the next five years, falling to about 5.82% in 2023. Finally, it is suggested to improve the low-efficiency sectors, improve the efficiency of internal factor allocation of industries, promote the upgrading of consumption structure and industrial structure, accelerate the development and opening up of knowledge-intensive service industry, improve human capital and accelerate frontier innovation, and improve total factor productivity and potential growth rate.

Keywords: total factor productivity, production function method, capital stock, potential growth rate

Contents

I. Development and Influencing Factors of Total Factor Productivity

As the main driving force for high-quality development, total factor productivity not only serves as a reference for the formulation of monetary policy, but is also one of the important variables that need to be concerned about in the overall macro-policy decision-making. The in-depth analysis and calculation of total factor productivity can help deconstruct the medium- and long-term development momentum of China's economy, and provide a powerful reference for short-term policy adjustment. This part systematically collates relevant literature on total factor productivity and lays the foundation for the research carried out by the research team.

i. Development of total factor productivity

The calculation of total factor productivity is the core and foundation of the calculation of production efficiency and the measurement of the quality of macroeconomic growth. Solow (1957) proposed and improved the concept of total factor productivity on the basis of studies by economists such as Tinbergen (1942) and Davis (1954), and quantitatively determined the relationship between macroeconomic output and the growth rate of input factors including total factor productivity by taking Solow residual as the indicator. Under the analytical framework of the Solow model, the factors of economic growth can be divided into three categories: the growth of labor force, the growth of capital stock and the growth of Solow residual. Kuznets (1955) believed that the contribution of capital to output growth was less than 30%. Therefore, the academic community generally believes that the input of production factors other than capital deserves more attention. Mankiw, Romer and Weil (1992) proposed the endogenous growth model based on the Solow model, regarding human capital as a growth factor within the model to measure changes in labor quality. The theory of endogenous growth focuses on the enormous contribution of human capital and further excludes the quality and efficiency of labor from the connotation of total factor productivity.

There are some differences in previous studies on the calculation of China's TFP growth rate. Most of the findings are optimistic about China's TFP growth rate from 1979 to 1998. For example, Chow and Li (2002) estimated that the TFP growth rate was about 2.68%, while Ye Yumin (2002)'s result was 4.59%. Some scholars believed that the contribution of TFP could reach 30%-58% between 1978 and 1995 (World Bank, 1997; Maddison, 1998). Through the regression data, Dong Minjie and Liang Yongmei (2013) concluded that from 1978 to 2010, the contribution of TFP, labor and capital to economic growth was about 10.9%, 3.7% and 85.4% respectively. The contribution of TFP was generally on the rise with large fluctuations before the 1990s. In 1992, it exceeded 50% at one point but basically showed a downward trend since then, until it was below 10% after 2005. In addition, many scholars believe that there are issues in the selection of data quality and data indicators in China, and different methods have great impact on the results of the calculation. Young (2003)'s calculation estimated China's TFP growth rate between 1979 and 1998 to be 1.4%. The calculation results of Wu Yanrui (2007) indicated that 27% of China's economic growth between 1993 and 2004 can be explained by the growth of TFP, far lower than the estimates of Germany and Japan (58% and 50%). Shu Yuan (1993) employed the production function method to estimate the TFP in China between 1952 and 1990, and believed that its growth rate was only 0.02%. Zhang Xiangsun (2008) used the DEA-Malmquist method to calculate the total factor productivity of each province from 1979 to 2005, and the results showed that the average growth rate was about 1.60%, while the contribution rate of TFP to economy was 16.57%. This paper argues that although capital input is the primary driving factor of China's rapid growth in the past, the improvement of total factor productivity has also played a very important role. A few arguments that the improvement of China's total factor productivity is slow are not advisable (Liu Shijin, Liu Peilin and He Jianwu, 2015).

ii. Internal and external factors affecting total factor productivity

Changes in the growth of total factor productivity can generally be interpreted as changes in technological progress, reform and innovation, institutional development and structural adjustment. Among them, the allocation efficiency of endogenous factors such as independent innovation and human capital is the internal factor that affects total factor productivity; institutional environment, fiscal policy, monetary policy, and foreign trade including technology introduction are external factors that affect total factor productivity.

1. Internal factors

With regard to internal factors, the study of Li Xiaoping and Lu Xianxiang (2007) argued that the growth of productivity within the sectors constituted the growth of China's manufacturing productivity, while the internationally recognized factor allocation dividend, i.e., the moving of capital and labor from low-productivity industries to high-productivity industries in economy entities, has not played a major role in China. Liu Wei and Zhang Hui (2008) divided the sample time since 1978 into six phases, and conducted research on changes in the technological progress and technological efficiency of the three major industries respectively. The results indicate that technological progress has a significant impact on China's economic growth. In consideration of the factor input, Cai Yuezhou and Fu Yifu (2017) decomposed the macro TFP into the effect of technological progress and the structural effect of factor flow allocation, and concluded that 1/3 of China's economic growth between 1978 to 2014 benefited from the continuous improvement of technological level, while the effect of structural adjustment was weak, accounting for only 20% of the technical effect. However, Yao Zhanqi (2009) adopted the frontier analysis method to analyze the re-allocation effect of labor factor flow from agriculture to the industrial sector and service industry. The empirical test showed that the adjustment of industrial structure and the re-allocation of resources have promoted the growth of China's TFP since 1993, and the contribution rate has shown an increasing trend, which is particularly important in future structural reforms. Liu Shijin et al. (2015) argued that the flow of factors from low-productivity agricultural sectors to high-productivity non-agricultural sectors (especially manufacturing) was also an important source of the improvement of total factor productivity since the reform and opening up. Liu Wei and Li Shaorong (2002) put that the industrial structure determined the mode of economic growth in a certain sense, in which the structural expansion of the tertiary industry would reduce the positive effects of the primary and secondary industries on the scale of the economy, and the main task of improving the overall factor productivity was to enhance the efficiency of the first and second industries. Therefore, the continuous adjustment of industrial structure would cast a great impact on the change of China's total factor productivity.

It is generally believed that technological independent innovation at the internal level plays an important role in China's TFP growth, and the innovation ability, management level, intellectual capital and corporate governance of enterprises at the micro level can all have an impact on this factor. Currently, as the efficiency of China's factor allocation is not satisfactory, it is necessary to accelerate the flow and optimal allocation of land and other resources between urban and rural areas, promote the two-way flow of factor resources between urban and rural areas with the focus on improving the allocation and utilization efficiency of land resources (Liu Shijin, 2015). In the future, under the expectation of gradual decline of the late-development advantage, focus should be placed on improving the efficiency and level of transformational structure, so as to allocate factor resources to a higher level and achieve the growth of TFP (Cai Yuezhou and Fu Yifu, 2017).

2. External factors

Foreign trade is an important external factor affecting the growth of TFP, mainly including technology introduction and foreign investment. Technological catch-up is one of the main reasons for the rapid increase in productivity in China (Liu Shijin, Liu Peilin and He Jianwu, 2015). China is still a developing country, and the catch-up effect is obvious. At this stage, China should focus on introducing advanced technologies from abroad to upgrade the domestic technological level. Trade affects the industrial structure, factor allocation and the effect of technological catch-up, and also directly affects the total growth and efficiency improvement of China's industries (Lin Yifu and Ren Ruoen, 2007). Liu Shijin, Liu Peilin and He Jianwu (2015) found that attracting foreign investment has enabled China to absorb advanced technology and management experience while utilizing foreign capital; the entry of multinational companies makes it easier for China to introduce advanced foreign technologies; the opening to foreign markets has not only expanded the Chinese market and deepened the division of labor, but also improved the technical level of imported intermediate input products and capital goods, and hence improved the overall technical level of export commodities. Jiang Xiaojuan et al. (2009) mentioned in Service Globalization and Service Outsourcing: Status, Trends, and Theoretical Analysis[1] that through the reform and opening up, the system of global service outsourcing has been improved, which is of great significance for improving the overall efficiency of China's service industry. However, there are still different viewpoints. Based on the empirical results of panel data of 27 provinces from 1979 to 2006, Liu Shunjia (2008) argued that a lthough FDI contributed to the improvement of total factor productivity in the short term, in the long run, the international trade and FDI have crowded out the independent innovation capability of China at the internal level and affected the accumulation of human capital, which was not conducive to the improvement of China's total factor productivity. Similarly, Zhang Yanhong (2006) believed that imported technologies have crowded out the investment in domestic independent R&D input, which was not conducive to improving the total factor productivity.

Institutional environment as well as fiscal and monetary policies are also important external factors that affect China's total factor productivity. According to the analysis of Ping Xinqiao et al. (2017), the tax burden has a negative effect on the improvement of the total factor productivity of the service industry. In addition, as the improvement of the overall efficiency of the service industry will help improve the overall efficiency of the manufacturing industry, tax incentives

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[1] Wang Xiaojuan et al, Service Globalization and Service Outsourcing: Status, Trends, and Theoretical Analysis. Publisher: People's Publishing House. Published in 2018. ISBN:9787010072463

provided by the government for the service industry will have a domino effect. Wang Maotai concluded in the book Research on Total Factor Productivity Measurement of China's Service Industry and Its Influencing Factors[2] that the degree of marketization and industrial agglomeration can affect the efficiency of allocation and the economies of scale, thus affecting the total factor productivity of China's service industry. The research of Sun Yingjie and Lin Chun (2019) has shown that local government debt brought about by fiscal decentralization can promote the growth of total factor productivity by influencing technological progress. From the perspective of government consumption, public fiscal expenditure can be more focused on areas that can improve the quality of human capital on the whole, such as the continuous optimization of education system, basic research and human capital incentive mechanism (Liu Wei and Zhang Liyuan, 2018), thus changing the trend of total factor productivity. Similarly, creating a more efficient and reasonable corporate financing environment as well as improving the financial market systems are conducive to the promotion of individual micro-productivity of enterprises.

Extensive studies and calculations of total factor productivity have been carried out in some literatures and methods, but there are still some issues. The first problem is the ageing of research data. Currently, most academic researches on China's total factor productivity adopt the data before 2007. However, after the financial crisis in 2008, China's economy has undergone great changes. The structural reforms on the supply side have continued to deepen, the old and new driving forces have begun to change, and the macroeconomics has undergone

[2]Wang Maotai, Research on Total Factor Productivity Measurement of China's Service Industry and Its Influencing Factors. Publisher: The Economic Daily Press. Published in 2017. ISBN: 9787519601058

significant structural adjustments. Therefore, for the analysis of total factor productivity and macroeconomic growth after 2008, it is urgent to update and reconstruct the corresponding data. Second, there are deficiencies in the measurement of factors. For example, there is no unified understanding of the depreciation attribute of capital factor input and the amortization attribute of intangible assets, and there is a lack of comparison of inter-industry total factor productivity. Limited by data quality and availability in the 1990s, previous studies conducted by scholars focused on the macro data and provincial data that could be obtained easily, but the analysis of inter-industry production efficiency was insufficient, which only involved the industrial and agricultural sectors, and the time interval of analysis was also early. In general, there is still a lack of calculation and analysis of total factor productivity with higher frequencies of different industries and of all industries after 2008.

II. Calculation Method of Total Factor Productivity

i. Comparison of calculation methods of total factor productivity

The current methods used to calculate total factor productivity mainly include parametric method and non-parametric method. Parametric methods include the production function method, deterministic frontier method and stochastic frontier method, and the non-parametric method refers to the data envelopment method.

The production function method, also known as the growth accounting method and the Solow residual method, is the traditional method used by Solow to calculate total factor productivity when his model was proposed. The basic idea is to measure the growth rate of TFP with the remainder of the output growth rate minus the cumulative growth rate of each factor. This method has been continuously used for decades, and many scholars have constantly improved the model itself and the estimation methods of labor and capital factors, thus improving the accuracy and credibility of the method. It is not easy to change some of the basic assumptions in today's complex and mature systems, and identify a method to calculate the FTP index that conforms to the economic meaning while satisfying the requirements of existing systems (Lin Yifu and Ren Ruoen, 2007). Therefore, although the method still retains the assumption of a completely competitive market and the unchanged returns to scale, with its clear and intuitive model, it still occupies an important role in the calculation of total factor productivity.

The deterministic frontier method and the stochastic frontier method in the parametric method, as well as the data envelopment method in the non-parameter method, are all methods for estimating the total factor productivity by using the production frontier. The production frontier reflects the function relationship between the input portfolio and the maximum output of an economy, and the function relationship is used to measure the production efficiency of the economy or enterprise. The parametric method employs the least square method or the maximum likelihood estimation. First, the production function is constructed, which is usually represented by a transcendental logarithmic function or a CD function, and then the parameter estimation is performed based on the production function to obtain the production efficiency.

Another method that applies the frontier analysis is the non-parametric data envelopment model (DEA) method. The DEA method was first proposed by Charnes, Cooper and Rhodes (1978). Not involving the specific forms of production function and parameter estimation, it is also known as the non-parametric method.

The advantage of the DEA analysis method is that it can analyze multiple output efficiencies under the multi-input perspective, and decompose the productivity growth in a more detailed way without making prior assumption and parameter estimation on the production function structure, which generates higher accuracy of the model. However, it has some limitations. On the one hand, as the optimal solution of linear programming contains at least one result with efficiency of 1, the result is relatively rough; on the other hand, the non-parametric method has higher requirements for the observed samples and is generally not applicable to large sample sizes.

ii. Calculation method and data source of this paper

The research team believes that it is difficult to completely separate human capital from total factor productivity, and there is no unified estimation of human capital in current researches. Although most studies estimate human capital based on the education years, considering the complex factors affecting human capital, the variable of education years alone is not sufficient to reflect human capital. Therefore, the TFP growth rate calculated in this paper included the contribution of human capital. Based on the Solow model, this paper applied the classic C-D production function, and set the model for calculating the total factor productivity as follows:

$$Y = K^{\alpha} A_{(t)} L^{\beta} \qquad s.t. \alpha + \beta = 1 \qquad (1)$$

Specifically, Y represents economic output, K represents capital input, and L refers to labor input; α and β are capital output elasticity and labor output elasticity, which respectively measure the contribution shares of capital input and labor input in economic output. Based on the assumption of the C-D production function, the sum of the two is one. A (t) represents the total factor productivity in economic output and measures the efficiency performance of the economy.

Through the derivation and inferential reasoning of formula (1), it can be concluded that the growth rate of economic output is the sum of the growth rates of the latter three, as shown in formula (2):

$$\frac{\Delta Y}{Y}=\frac{\Delta A}{A}+\alpha\left(\frac{\Delta K}{K}\right)+(1-\alpha)\left(\frac{\Delta L}{L}\right) \qquad (2)$$

According to the above formula, the key to the accounting of total factor productivity growth lies in the reasonable calculation of capital input and labor input. Formula (2) conforms to the definition of Solow residual, which represents the important part of economic growth derived from technological progress, efficiency improvement, scale effect and other factors other than capital and labor. The calculation of total factor productivity is not only a summary of China's economic growth in the past, but also an important basis for improving the quality of economic development and promoting supply-side structural reform. In addition, by predicting the growth rate of capital stock, number of employed persons and total factor productivity in the next five years, the potential growth rate of China in the next five years can be estimated.

Limited by the availability of some data, the research team of this paper performed detailed and high-frequency independent calculations of economic growth, capital stock and labor force from 2006 to 2018, combined with the data released by the National Bureau of Statistics, mainly employing the production function method to calculate the annual TFP growth rate of all industries, the quarterly TFP growth rate of all industries, and the annual TFP growth rate of 19 industries during the sample period, and adopting the data envelopment method for verification. In order to obtain a longer TFP growth rate sequence, the research team cited the capital stock of a longer time series collected by Wang Wei et al. (2017) and the number of employed persons published in the statistical yearbook, and also adopted two methods to estimate the TFP growth rate from 1978 to 2018. In addition, in order to verify the reliability of the data measured by the research team, the research team referred to the research results of some representative institutions as supplementary verification.

Specifically, the data sources of the research team's calculation of the annual TFP growth rate of all industries (1979-2018) included: GDP data released by the National Bureau of Statistics; the data of capital stock obtained from the Reassessment of China's Capital Stock Based on Ten Major Categories: 1978-2016 by Wang Wei, Chen Jie and Mao Shengyong (2017), which was calculated by the research team to 2018; employment data from the National Bureau of Statistics. In order to calculate the growth rate of TFP over the years more accurately with the production function method, this paper drew on the data of income shares of capital factor and labor factor in China provided by the Conference Board. In addition, in order to verify the reliability of the calculation results, the results calculated in this paper were compared with those of the Penn World Table (PWT9.0), the United Nations Industrial Development Organization (UNIDO), and the Conference Board.

The data sources of the research team's calculation of the quarterly TFP growth rate of all industries (2006Q1-2018Q4) included: quarterly GDP data from the

National Bureau of Statistics; capital stock and the number of employed persons calculated by the research team; the data of income shares of factors from the Conference Board with assumption that the income shares of capital and labor remain unchanged within the year.

The data sources of the research team's calculation of the annual TFP growth rate of 19 industries (2006-2018) included: GDP data, capital stock data and employment data of 19 industries from 2005 to 2018 estimated by the research team according to the data released by the National Bureau of Statistics.

III. Calculation of Annual Total Factor Productivity Growth Rate of All Industries from 1978 to 2018

i. Calculation of capital inputs

The data source of capital stock was from the Reassessment of China's Capital Stock Based on Ten Major Categories: 1978-2016 by Wang Wei, Chen Jie and Mao Shengyong (2017). The perpetual inventory method commonly used was adopted as the calculation method with the basic principle of

$$K_t = (1-\delta_t)\ K_{t-1} + I_t \qquad (3)$$

In this formula, Kt represents the capital stock in year t, δt is the depreciation coefficient, which represents the depreciation ratio of capital in year t, and It is the new capital input in year t.

China's capital stock and growth rate from 1978 to 2018 are shown in the following figure:

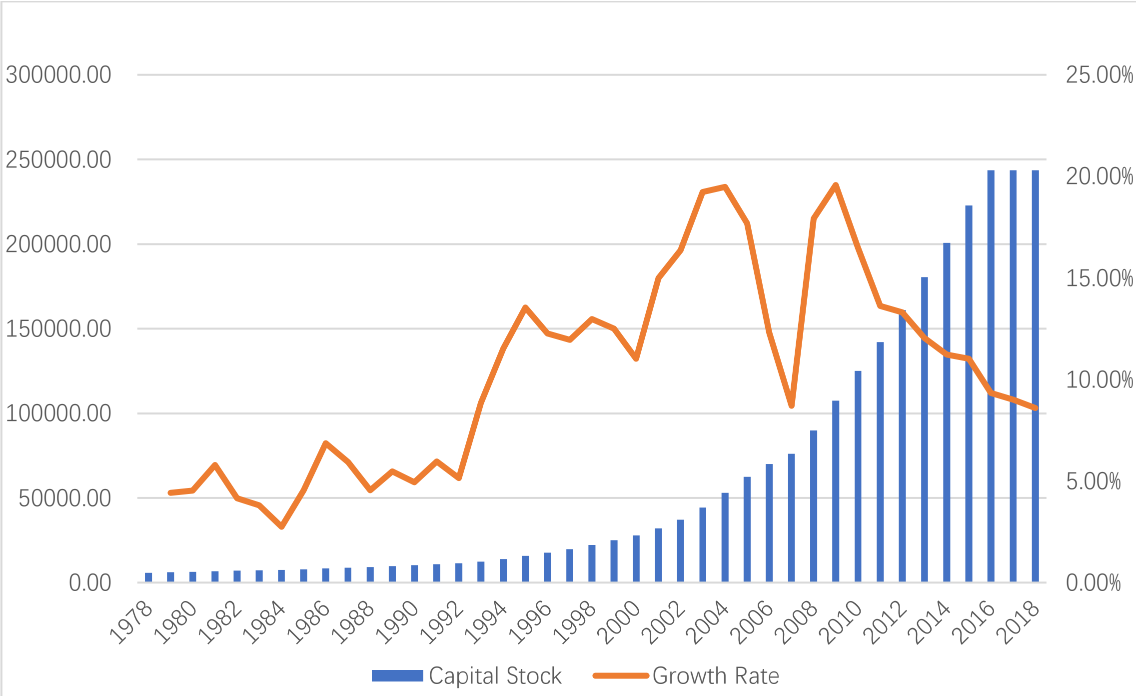

Figure 1 Changes in China's Capital Stock and Growth Rate (1978-2018)

As can be seen from Figure 1, before 2003, the growth rate of China's capital stock presented a fluctuating upward trend, and was generally in a high growth range. The growth rate once reached 19.49% in 2003, and the increase of capital stock was significant. After 2003, the growth rate dropped rapidly, and fell to the bottom of 8.71% in 2006. However, from 2006 to 2008, there was a V-shaped reversal, and the growth rate of capital stock rebounded rapidly, reaching its peak since the beginning of this century in 2008. After the financial crisis, the growth rate of capital stock continued to decline, from 19.57% in 2008 to 8.6% in 2018. In general, China's capital stock has been growing since the reform and opening up, with an average annual growth rate of 10.36% and the peak value of 19.57% before the 2009 financial crisis. However, as China's economy gradually shifts from a high-speed growth phase to a medium-speed high-quality development stage, it is difficult to sustain the high investment brought about by the competitive and crowding growth in the past, and there is a high probability that the growth rate of capital stock will continue to decline. In the medium and long term, the growth rate of China's capital stock may be at a level of 8% or even below 8% for a long time.

ii. Measurement of input of labor factors

Most of Western academic scholars measure the input of labor factors by "number of employees × labor hours" according to the Measuring Productivity OECD Manual. Due to relatively low credibility of China's labor hours and lack of data sources, Chinese academic scholars usually adopt the traditional labor population for measurement. In addition, many scholars also take human capital into account as an endogenous factor to supplement the input for measuring labor factors. At present, the variable "years of education " is mostly used to measure human capital in research. However, the rationality and effectiveness of this variable are questioned, because this approach can neither link the value of human capital with money, nor explain the difference in the actual output of money under the same years of education. In addition, the difference in the rate of return at different stages of education is not reflected. In addition, given the factor of "learning by doing", this approach may seriously underestimate the human capital of uneducated populations. Therefore, this paper uses the most basic labor population to estimate the total input of labor factors. Although this approach is more general, it can comprehensively include the possibilities of labor factors, and the stability and authenticity of the data can be guaranteed.

Figure 2 Variation Trends in the Number and Growth Rate of China's Labor Force (1978-2018)

As at 2017, the research team estimates that China's employment population has been on the rise, with an average growth rate of 1.31%. At the beginning of reform and opening up, China's employment population grew rapidly, with an average annual growth rate of 3.07%; between 1989 and 2001, the annual growth rate of China's employment population was stable at around 1%; the average annual growth rate during 2002-2018 decreased to 0.38%. In 2018, the growth rate of China's employment population fell to a negative value (-0.07%) for the first time. In the medium and long term, the negative growth may be inevitable. This trend is consistent with the predictions of most of domestic research institutions (Sheng Laiyun, 2018).

iii. Labor and capital shares of income

In the classical C-D production function, the elasticity of labor and capital factors measures the greatest effect of the growth of unit labor and capital factors on promoting economic growth. Kuznets (1957) used European countries as an example to study the capital share of income. It is considered to be normal that the capital share of income is around 30%. The measurement of the shares of the two factors is directly related to the structure of the national macro-economy and the decomposition of national income. There are two popular measurement methods in the academic circle. One is to estimate the proportion of the two factors by measuring the proportion of labor remuneration in national income, which is the income shares method; and the other is to make regression analysis of per capita output and per capita capital stock by means of measurement, which is the measurement method. This paper mainly used the share measured by the Conference Board for a long time, but the data has deficiency after 2016. Considering little change in the factor share in a short period, the research team used the value of 2016 instead of the values of 2017 and 2018. At the same time, the research team used the average of income share of the two factors and DEA measurement method to supplement the validation.

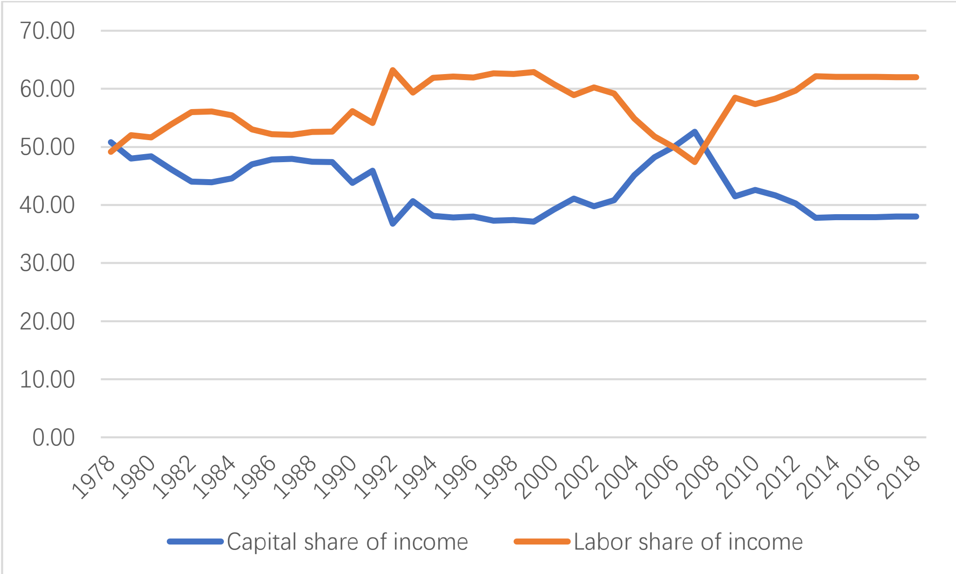

Figure 3 China's Capital and Labor Shares of Income and Variation Trends (1978-2018)

Figure 3 shows the overall trend chart for China's constantly fluctuating capital share of income and labor share of income (by Conference Board) used in this paper. According to the figure, after the reform and opening up, the proportion of labor factors in economic output in China's economic development was basically higher than that of capital factors, and the proportion of capital factors was slightly higher only in 2007. In general, the average labor share of income in China was 57.22%, and the average capital share of income was 42.78%, which was less fluctuating.

iv. Calculation result of total factor productivity growth from 1978 to 2018

Based on the above calculation of capital factors, labor factors and their income shares, the research team used the production function method to measure the growth rate of industry-wide TFP from 1978 to 2018, and used DEA method for validation analysis. In addition, based on the capital stock and employment population for 2006-2018 after independent calculation, the research team used the same method to measure the growth rate of TFP during the sample period as a validation reference. Finally, the research team selected some representative research results for comparative analysis.

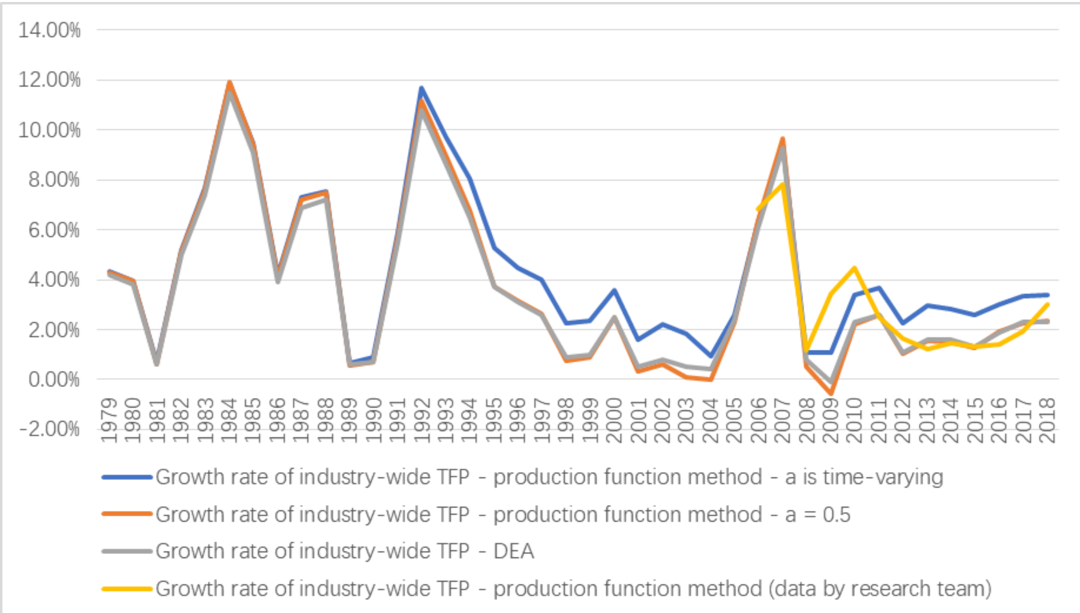

Figure 4 Measurement Results of Growth Rate of Four TFPs (1978-2018)

Figure 4 shows the measurement results of TFP growth rates by four different methods. It is easy to see that the trends by four methods are basically the same, with differences in the level values. Specifically, the TFP growth rate by time-varying share (by the Conference Board), the TFP growth rate by the average share (α = 0.5), and the TFP growth rate by the DEA method had generally the same fluctuations. However, for the decline interval of the second and third stages, the TFP growth rate by time-varying share (by the Conference Board) was significantly higher than the growth rate of other two types, and the difference values were stable, indicating the TFP growth rates by the DEA method and by the average share (α =

0.5) may had underestimated risk during the decline stage. In addition, although the estimated capital stock and employment data by the research team last for a relatively short period, the changing trend of the TFP growth rates are consistent with the long-term sequence results, which can verify the reliability of quarterly industry-wide and annual sub-industry TFP growth rates by the data of the research team. In this paper, the research team used the TFP growth rate by time-varying share (by Conference Board) as the main research object.

According to the figure, the broken line fluctuated greatly after the reform and opening up, but the average TFP growth rate was approximately 4.39%, which is in line with 3.7% by Lu Yang (2016) and 4.1% by Li (2016) to a certain extent. However, there are also many differences due to differences in the measurement methods and data.

According to the measurement results, since 1978, China's TFP growth rate has experienced three peaks, namely 1984, 1992 and 2007, respectively, with growth rates of 11.87%, 11.69% and 9.43% respectively. The three peaks can be generally divided into three stages: The first stage is from 1978 to 1990, with an average TFP growth rate of 5.31%; the second stage is from 1991 to 2004, with an average growth rate of 4.56%; and the third stage is from 2005 to 2013, with an average growth rate of 3.65%. The three stages show very similar rules, all of which drastically reach the peak after the initial rapid rise and then fluctuate and decline, and the average levels of the three stages gradually move down. From the common characteristics of the three stages, China's three rounds of TFP growth are basically reflected in pulses: The growth rate sharply fluctuated and rose in the initial stage, and declined slowly in the middle and late stages, which is possibly because the improvement of China's technical efficiency was achieved by accepting the impact; and the subsequent digestion of impact was reflected in the steady decline in efficiency growth. However, in the past five years, there has not been a similar rule. The TFP growth rate was generally stable at approximately 3%. In 2016, the TFP growth rate showed an inflection point from down to up.

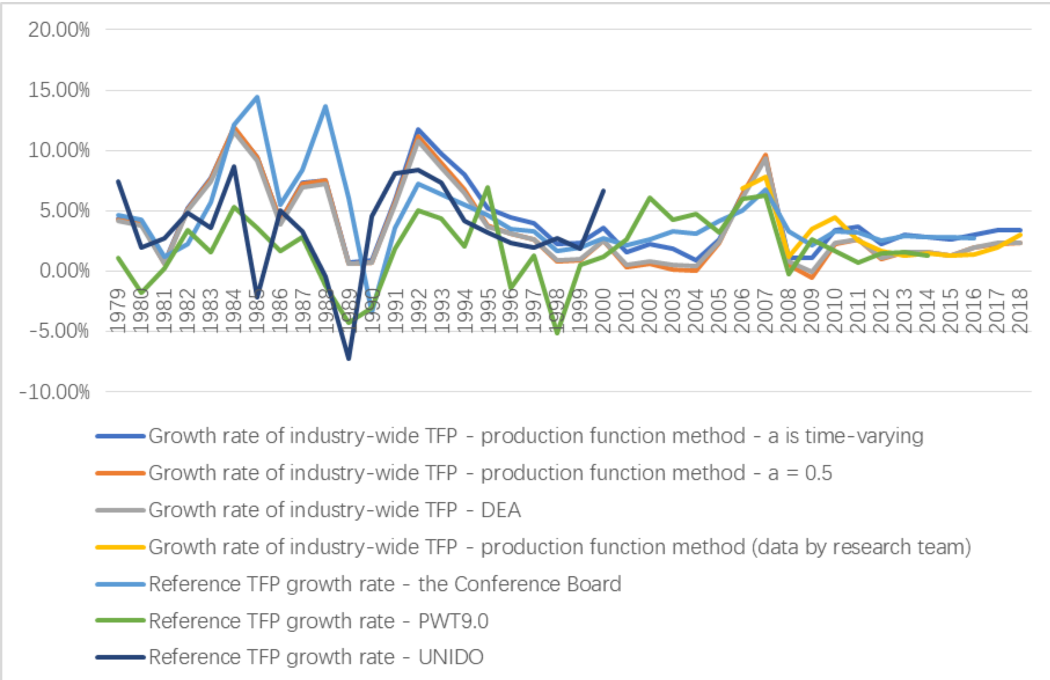

Figure 5 Comparison of the Calculation Results of TFP Growth Rate of This Paper with Other Institutions (1978-2018)

Figure 5 shows the comparison of the major measurement results of this paper with other institutions. From the stage characteristics, in the first stage from 1978 to 1990, the calculation results of various institutions showed larger fluctuations in growth rate, and there was a negative growth of TFP before and after 1990. However, the growth rate by UNIDO and PWT9 was relatively low. In the second stage, the calculation results by PWT9.0 are the most special. The results showed that there were two lows in China's TFP growth rate in 1996 and 1998, which largely differ from other institutions. The difference between the calculations of the first two stages by different institutions may mainly be attributed to the problem of data quality. In addition, in the period of large economic reform in China, the use of different data and measurement methods will lead to larger deviation of the results. In and after the third stage, the basic framework of China's economic reform has been formed, and the data quality was generally stable. Therefore, the measurement results by different data and measurement methods showed great similarities. According to the measurement results, all parties believe that in 2007, China's TFP growth rate showed a latest peak. After that, the growth rate slowly declined and constantly fluctuated around 3%. Numerically, the measurement results by PWT9.0 were as at 2014 and tended to be conservative, which are basically lower than that of other institutions, with an average of approximately 1.9%; the measurement by UNIDO only covered 1979-2000, with certain limitations, and the average was approximately 3.6%; the Conference Board's measurement lasted until 2016, which is of higher credibility, and the average was 4.42%, which is significantly higher than that of other institutions.

IV. Calculation of Quarterly Total Factor Productivity Growth Rate of All Industries from 2006 to 2018

After the reliability of sub-item data estimated by the research team in the short time series is verified, the annual data is split into quarterly data to measure the growth rate of quarterly industry-wide TFP of higher-frequency. The production function method is also used in this section to measure quarterly data, and the DEA method is adopted for comparison. The quarterly GDP data comes from the

National Bureau of Statistics. The quarterly capital stock and employment population are estimated by the research team. The factor income share data comes from the Conference Board, and it is assumed that the capital and labor shares of income does not change during the year.

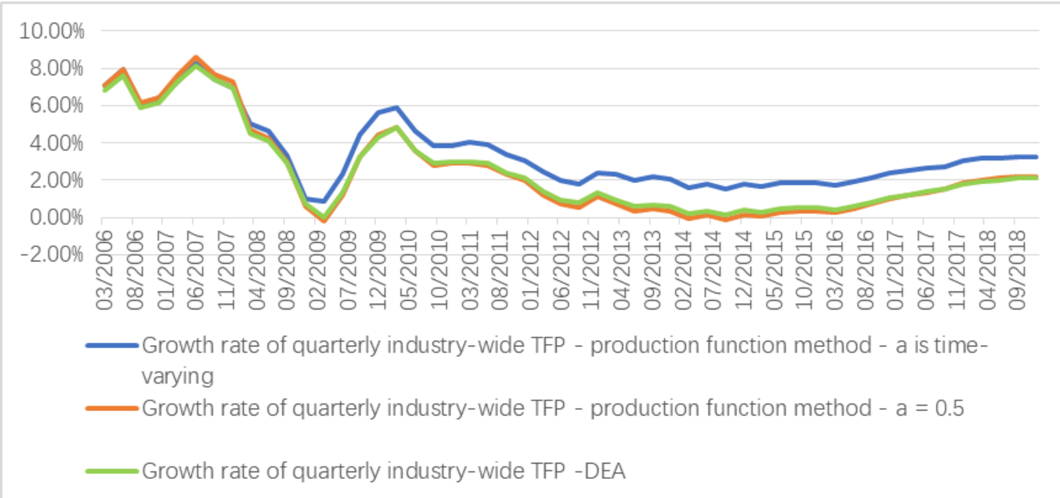

Figure 6 Comparison of the Measurement Results of Growth Rate of Quarterly Industry-wide TFP (2006q1-2018q4)

Figure 6 shows that the TFP growth rate by the production function method and the DEA method is generally the same. In the years before the financial crisis, China's growth rate of quarterly TFP could still fluctuate around 6%-8%; before and after the financial crisis, TFP growth rate declined sharply, and fell to the lowest point in Q1 of 2009; subsequently, it rebounded in a certain range, followed by continued fluctuation and decline, and the inflection point from down to up appeared in Q1 of 2016.

According to the results by the production function method, the peak TFP growth rate during the sample period occurred in Q2 of 2007, which was 8.26%; the second peak appeared in Q1 of 2010, which was 5.91%; there was a temporary sharp decline in growth rate between the two peaks. The growth rate dropped sharply. Both the TFP in Q4 of 2008 and Q1 of 2009 was less than 1%. The quarterly average TFP growth rate by this measurement method was 3.46%, which is in line with the annual average. The value by the DEA method is generally low. The lowest value was -0.01% in Q1 of 2009, and the average quarterly growth rate was approximately 2.48%, which is significantly lower than that by the production function method.

V. Calculation of Annual Total Factor Productivity Growth Rate by Industry from 2006 to 2018

Based on the GDP, capital stock and employment population data of 19 industries from 2005 to 2018 measured by the research team, the production function method is used in this section to measure the TFP growth rates in the three industries from 2006 to 2018 and the TFP growth rate in 19 industries respectively, and the DEA method is used for comparison validation. By comparison, the results by the two measurement methods are basically the same. This section makes analysis mainly based on the calculation results by the production function method.

i. Analysis of total factor productivity growth rate of the tertiary industry

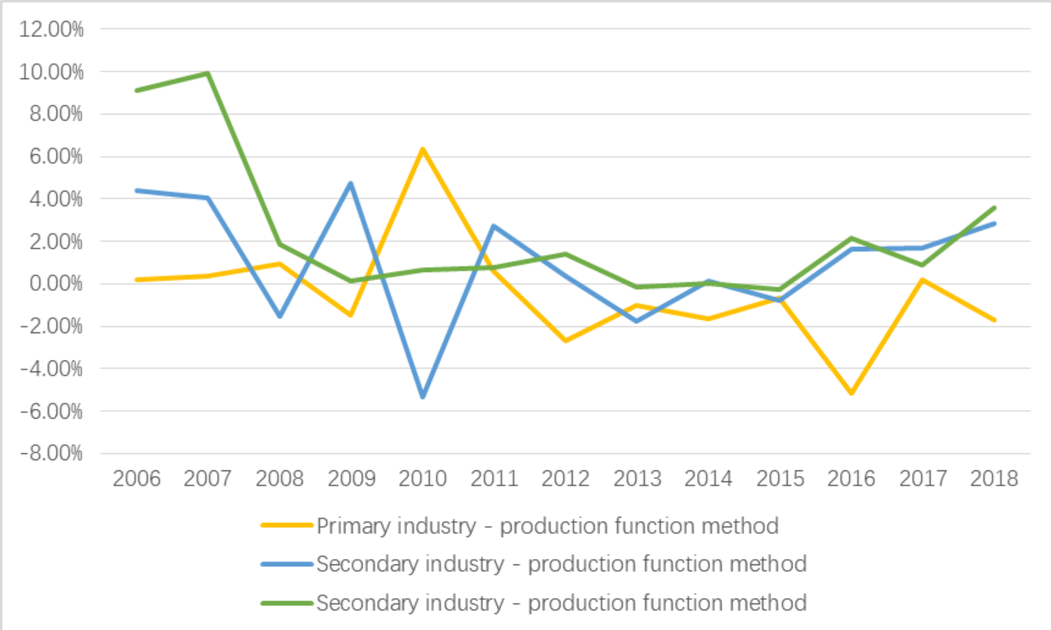

Figure 7 TFP Growth Rates of Three Industries (Production Function Method)

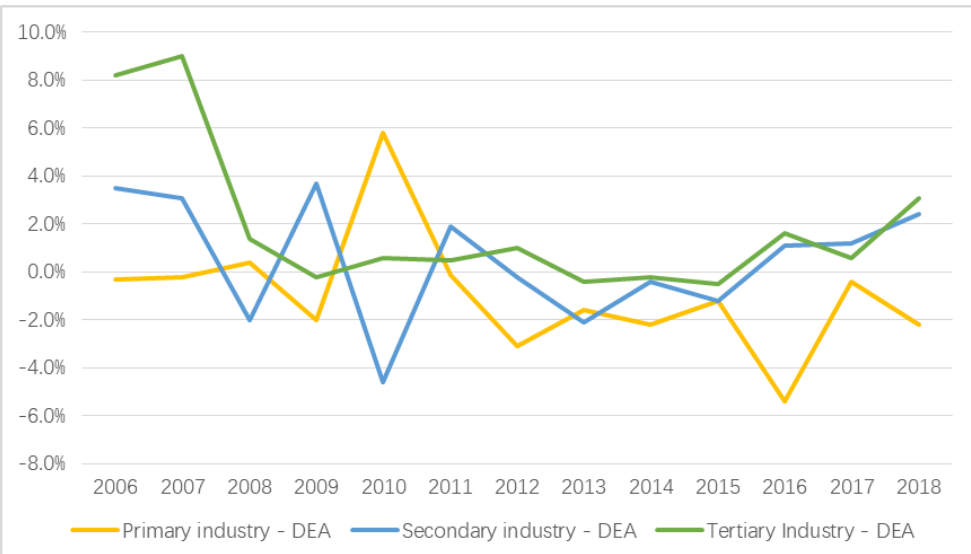

Figure 8 TFP Growth Rates of Three Industries (DEA)

The growth rate of TPP in the primary industry fluctuated and declined from 2006 to 2018. From the stages, the growth rate of TFP in the primary industry from

2006 to 2009 fluctuated slightly and steadily, with an average annual growth rate of only -0.07%; in 2010, the growth rate of TFP in the primary industry rebounded sharply, reaching the peak during the sample period, and then rapidly declined; since 2012, the growth rate of TFP in the primary industry has been basically negative, which slightly fluctuated and declined. The average growth rate from 2012 to 2018 was -1.68%.

The growth rate of TFP in the secondary industry showed a volatility decline from 2006 to 2018, followed by a volatility increase. From the stages, from 2006 to 2007, the growth rate of TFP in the secondary industry was higher, which was above 4.0%; from 2008 to 2013, the growth rate of TFP in the secondary industry fluctuated drastically, with an average annual growth rate of -0.09%, and it reached the peak in 2010 during the sample period; from 2013 to 2018, the growth rate of TFP in the secondary industry showed a volatility increase, with an average annual TFP growth rate of 1.10%, and it rose to approximately 3% in 2018.

The growth rate of TFP in the tertiary industry generally showed a drastic decline and then stabilized, followed by a volatility increase. From the stages, from 2006 to 2007, the growth rate of TFP in the tertiary industry was at the highest position during the sample period, which was above 9%; from 2008 to 2015, the growth rate of TFP in the tertiary industry fluctuated slightly, with an average annual growth rate of 0.37%; after 2015, the growth rate of TFP in the tertiary industry showed a volatility increase, with an average annual growth rate of 2.20%, and it exceeded 3% in 2018.

In comparison, the growth rate of TFP among the three industries has larger differences. During the sample period from 2006 to 2018, the average annual growth rate of TFP in the tertiary industry was the highest, being 1.72%; the secondary industry ranked second with 0.70%; The average annual growth rate of TFP in the primary industry was -0.53%, which is in negative growth. After the financial crisis, the growth rate of TFP in the three industries showed a declining trend, which is basically consistent with the existing research results. However, before and after 2013, the growth rate of TFP in the three industries began to be different. The growth rate of TFP in the secondary and tertiary industries showed a volatility increase, and the growth rate of TFP in the tertiary industry was basically slightly higher than that in the secondary industry, while the growth rate of TFP in the primary industry continued a volatility decrease.

Technology catch-up and structural changes are important sources of improvement of TFP for a late chaser. In the past 30 years, the structural adjustment brought about by the cross-industry allocation has contributed significantly to the growth of TFP. However, as the transfer rate of rural labor slowed down, the space for the inter-industry allocation of factors to gradually increase the growth of TFP was gradually narrowed. Since the "13th Five-Year Plan", with the comprehensive deepening of the supply-side reform, and the enhanced elimination of backward production capacity and industrial restructuring, the efficiency of resource allocation has continued to improve, the institutional conditions and policy environment have been continuously optimized, and more factors have flowed from low-productivity enterprises, industries and regions to high-productivity enterprises, industries and regions, and the improved efficiency of factor resource allocation in industries and sectors has led to a steady increase in TFP growth.

ii. Analysis of total factor productivity growth rate of sub-segments

1. **Agriculture, forestry, animal husbandry, and fishery**

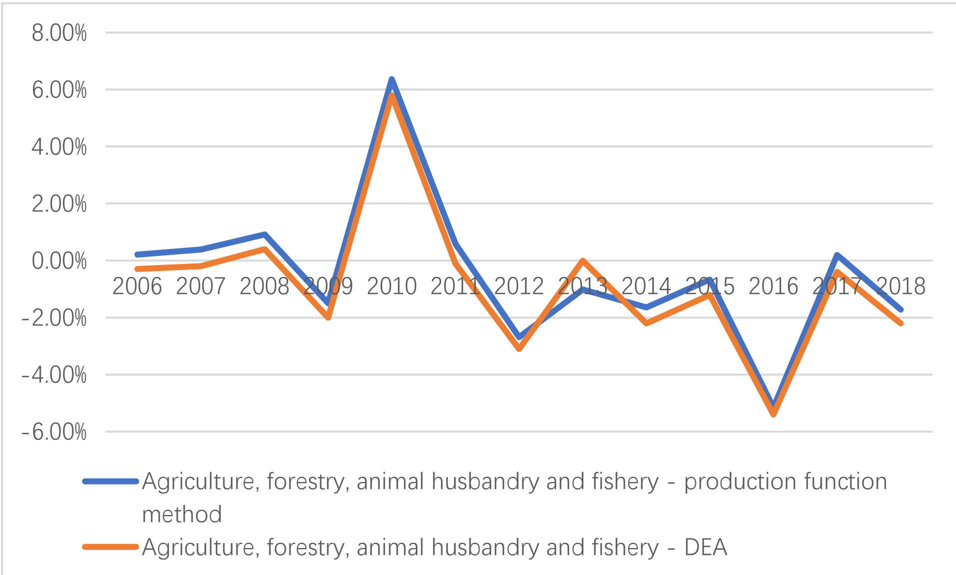

Figure 9 Growth Rate of TFP in Agriculture, Forestry, Animal Husbandry and Fishery from 2006 to 2018

2. **Mining industry**

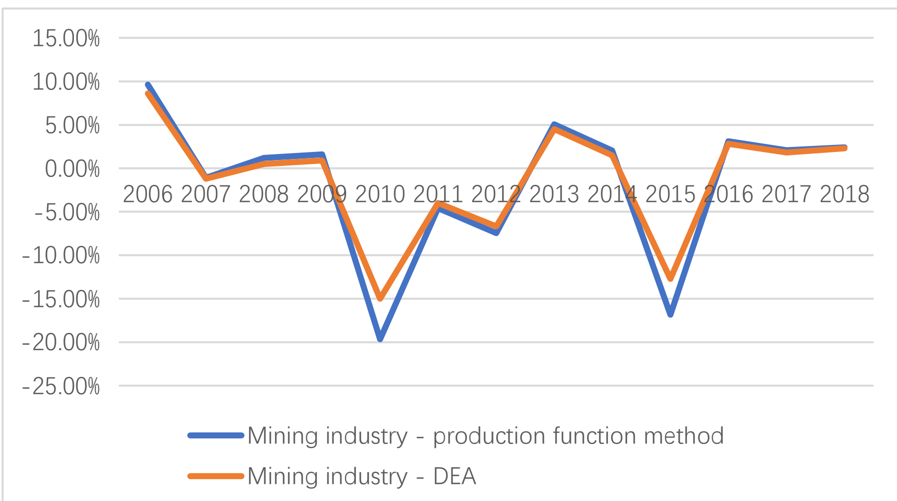

Figure 10 Growth Rate of TFP in the Mining Industry from 2006 to 2018

From 2006 to 2018, the growth rate of TFP in the mining industry fluctuated greatly. In 2010 and 2015, there were two valleys with a growth rate of approximately -15% and -13% respectively. After 2016, the growth rate of TFP in the mining industry tended to be steady, with an average annual growth rate of more than 2%.

3. Manufacturing

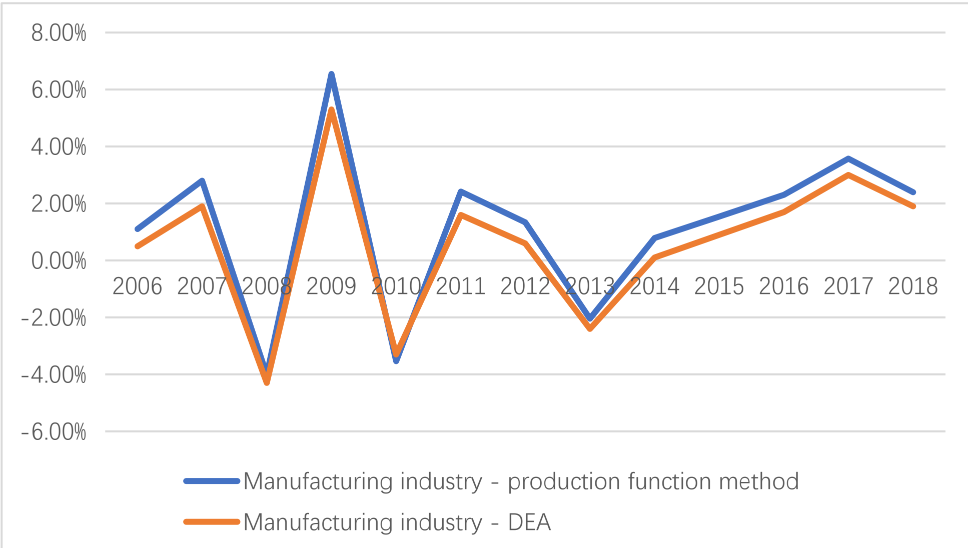

Figure 11 Growth Rate of TFP in the Manufacturing Industry from 2006 to 2018

From 2006 to 2018, the growth rate of TFP in the manufacturing industry swung drastically, followed by a steady rise. After 2013, the growth rate of TFP in the manufacturing industry steadily increased. It rose to approximately 3.6% in 2017, and fell slightly to 2% in 2018.

4. Production and supply of electricity, gas and water

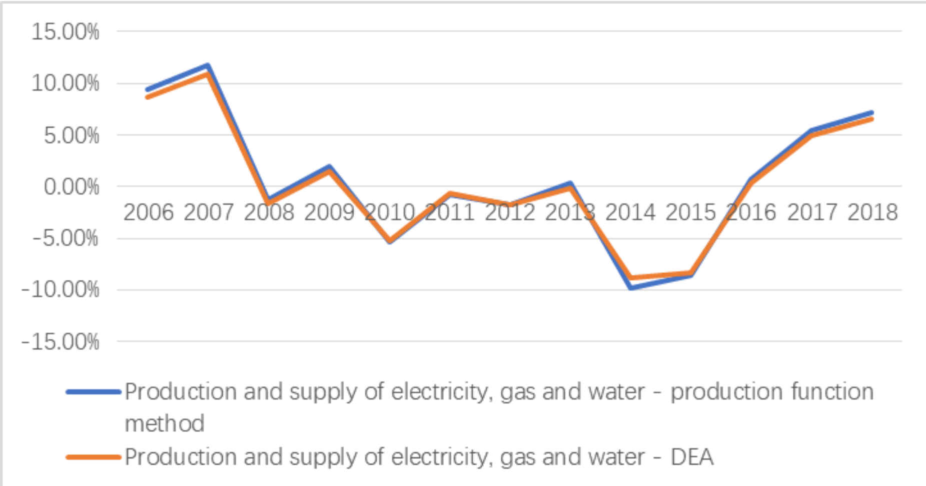

Figure 12 Growth Rate of TFP in Production and Supply of Electricity, Gas and Water from 2006 to 2018

From 2006 to 2018, the growth rate of TPP in the production and supply of electricity, gas and water showed a drastic rise after a volatility decline. From 2006 to 2014, the growth rate of TFP had a volatility decline. After that, the growth rate of TFP increased steadily. The growth rate slowed down after 2016, and it reached 7% in 2018.

5. Construction

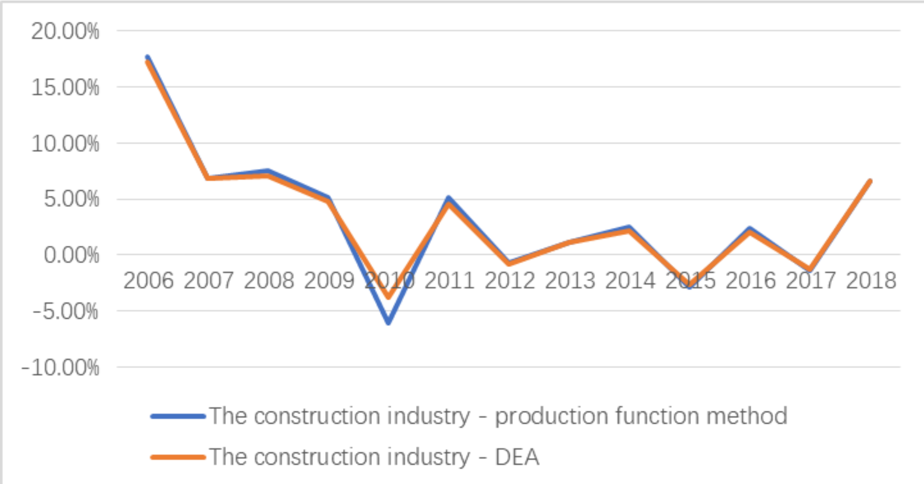

Figure 13 Growth Rate of TFP in the Construction Industry from 2006 to 2018

From 2006 to 2018, the growth rate of TFP in the construction industry declined rapidly at first and then swung continuously. 2006 was the peak in the sample period, and it was speculated that the TFP growth rate of the construction industry was at a high level before 2006. In 2010, it reached the valley in the sample period and rose greatly to 6.6% in 2018.

6. Transportation, storage and postal industry

From 2006 to 2018, the growth rate of TFP in transportation, storage and postal industry declined rapidly at first, and then swung greatly to rise by degrees. Specifically, the growth rate of TFP declined rapidly from 2006 to 2008, reaching the valley during the sample period in 2008. Since 2010, the TFP has swung to rise, and the range of fluctuation has gradually decreased, reaching about 4% in 2018.

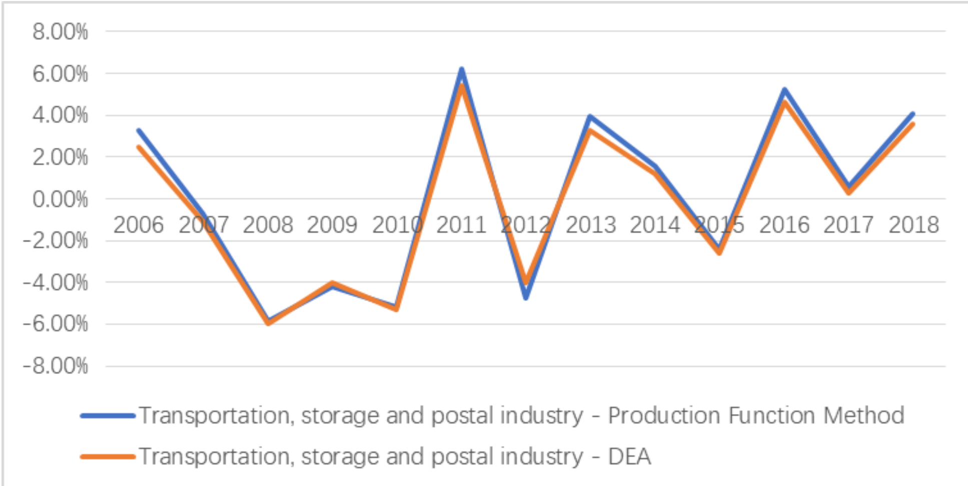

Figure 14 Growth Rate of TFP in the Transportation, Storage and Postal Industry from 2006 to 2018

7. Information transmission, computer service, and software

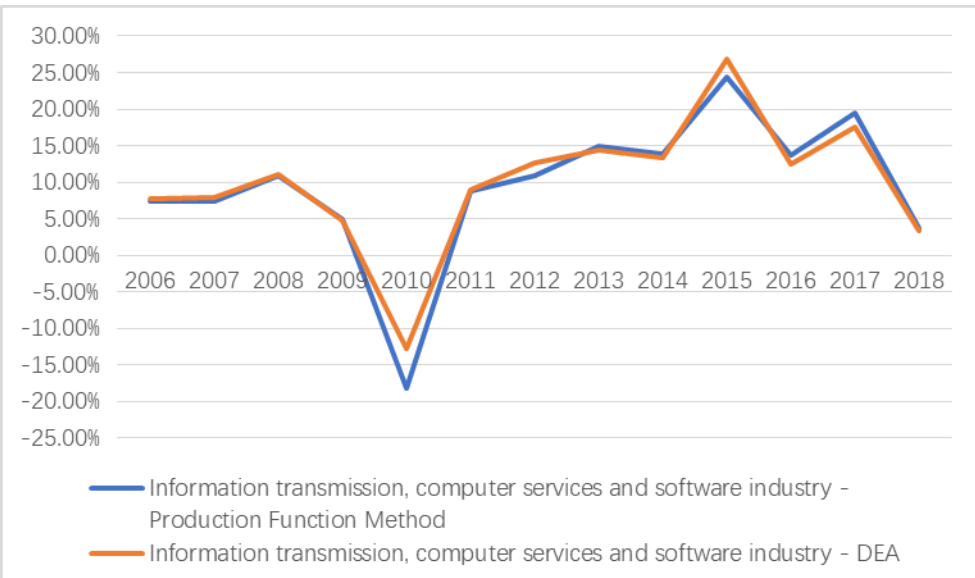

Figure 15 Growth Rate of TFP in the Information Transmission, Computer Services and Software Industry from 2006 to 2018

From 2006 to 2018, the growth rate of TFP in information transmission, computer services and software industry showed obvious periodicity. The first phase is 2006-2010. After several years of stable operation, TFP growth fluctuated to decline, reaching the valley of the whole sample period in 2010, as low as -20%. The second phase is 2011-2015. TFP growth has been rising substantially and continuously, with an average annual growth rate of 15.90%, and reached the peak in the sample period in 2015. The third phase is 2016-2018. TFP growth fluctuated to decline, and there was a sharp drop in 2018, down to about 3%.

8. Wholesale and retail trade

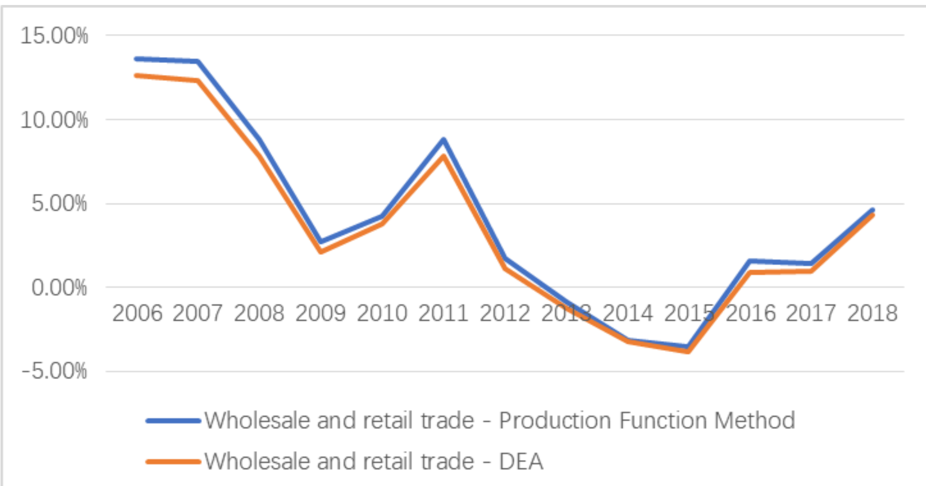

Figure 16 Growth Rate of TFP in the Wholesale and Retail Trade from 2006 to 2018

From 2006 to 2018, the TFP growth rate of wholesale and retail trade showed obvious cyclical fluctuations, experiencing two rounds of "first down then up". From 2006 to 2011, TFP growth slowed down to a low of about 3% in 2009, and then rebounded to a high of about 9% in 2011. From 2011 to 2018, the growth rate of TFP first declined to a low of -4% in 2016, and then rose to a high of about 4% in 2018.

9. Accommodation and catering

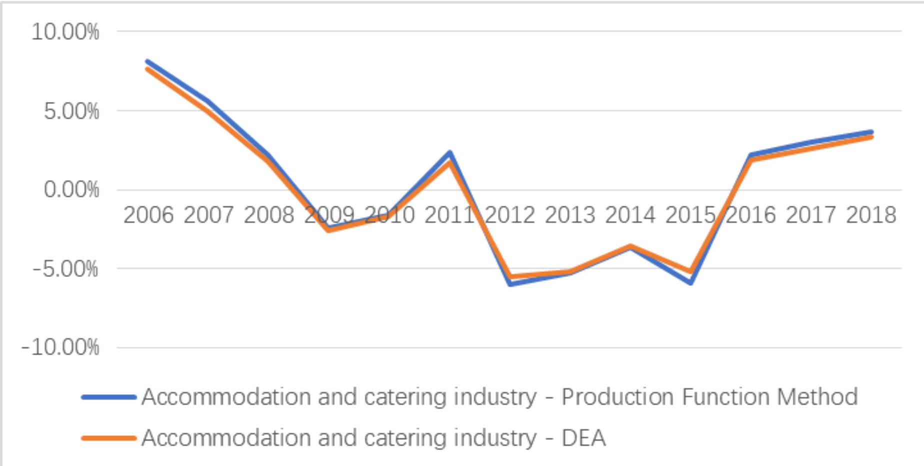

Figure 17 Growth Rate of TFP in the Accommodation and Catering Industry from 2006 to 2018

Growth rate of TFP in the accommodation and catering industry from 2006 to 2018 first declined and then went up. The overall downward trend was observed in 2006-2015, although there was a brief rebound in 2009-2011. Since 2015, the growth rate of TFP has rebounded rapidly, but the rebound has slowed down in the past two years, reaching about 3.5% in 2018.

10. Finance

From 2006 to 2018, the finance showed two times of rapid rebound after dropping back. In 2006-2012, the growth rate of TFP first fell from a high level, peaked at over 30% in 2007, and then fell to a valley of -20% in 2011 before rising to about 10% in 2012. From 2012 to 2018, TFP growth rate slowed down slightly. In 2016, there was an inflection point that the downward trend went into reverse, and in 2018, it was at the level of 6%.

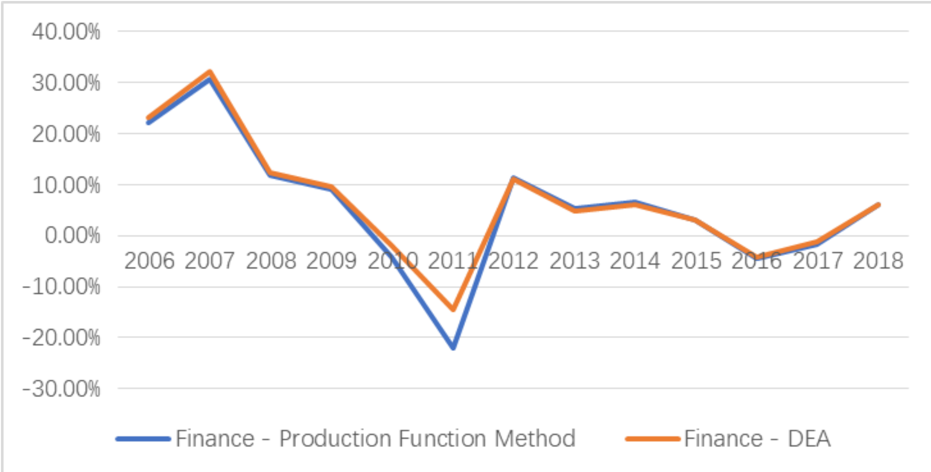

Figure 18 Growth Rate of TFP in the Finance from 2006 to 2018

11. Real estate

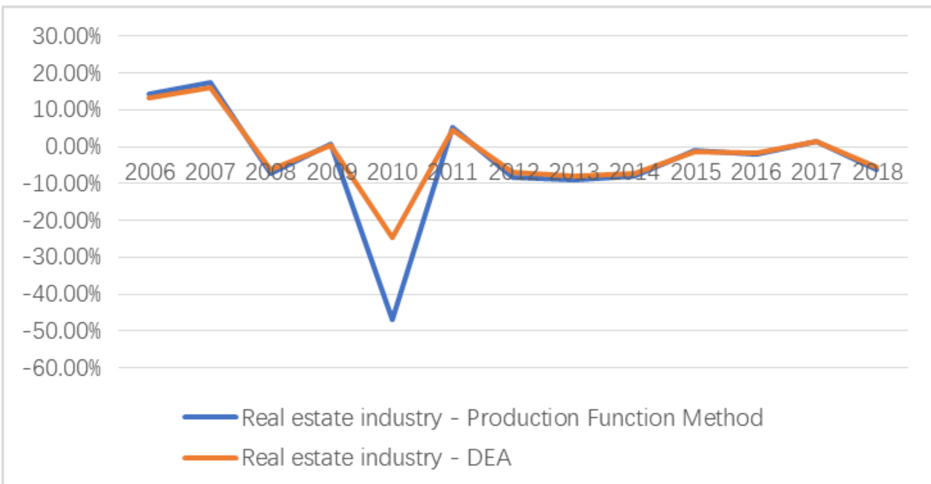

Figure 19 Growth Rate of TFP in the Real Estate Industry from 2006 to 2018

The growth rate of TFP in real estate industry from 2006 to 2018 can be roughly divided into two phases. The first phase is 2006-2011. The overall fluctuation range of TFP was relatively large. At first, TFP fluctuated to decline, reaching a very low value of -50% in 2010, and then rebounded to a positive value in 2011. The second phase is 2011-2018. The fluctuation range of TFP growth rate was relatively small, with a rebound was observed in 2012. There was an inflection point in 2017. The TFP growth rate fell back to about -5% in 2018.

12. Leasing and business service industry

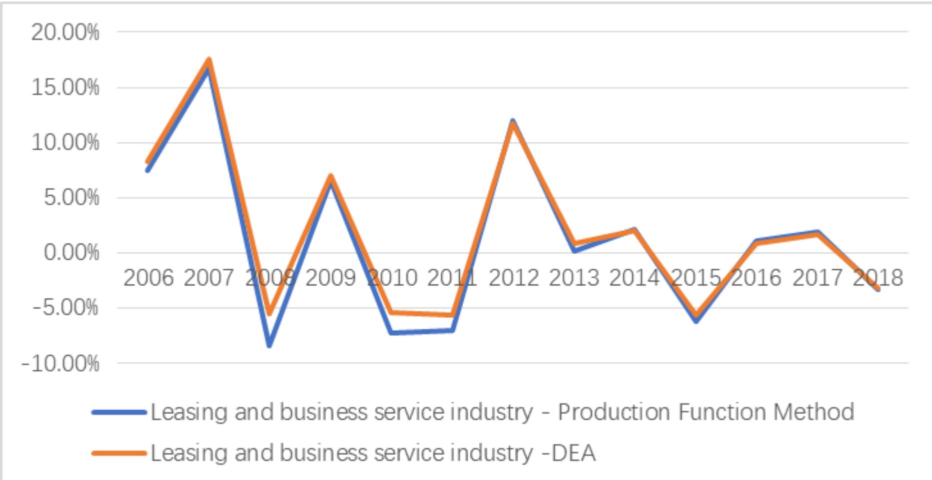

Figure 20 Growth Rate of TFP in the Leasing and Business Service Industry from 2006 to 2018

From 2006 to 2018, the growth rate of TFP in leasing and business service industry showed heavy swings, but the range of swings gradually slowed down. The average annual growth rate was 1.59% in 2006-2012, -0.97% in 2013-2018 and fell back to about -3% in 2018.

13. Scientific research, technical service, and geological exploration

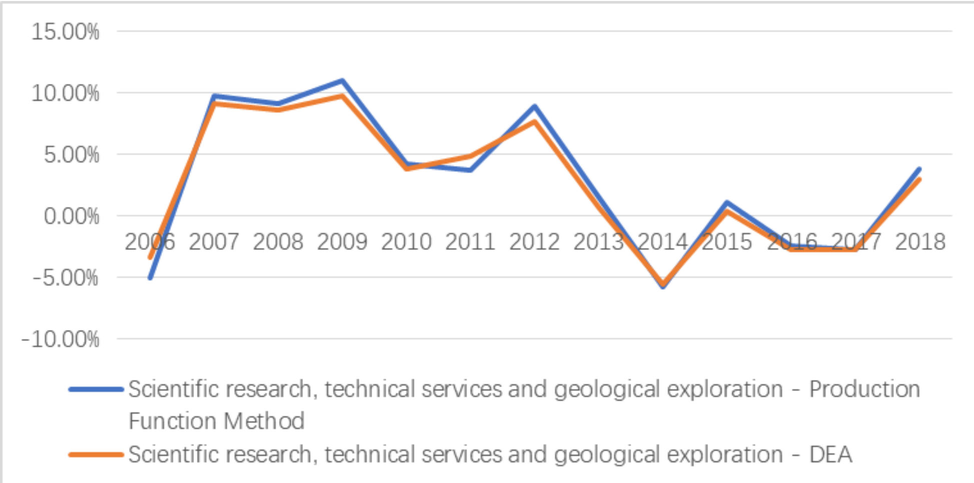

Figure 21 Growth Rate of TFP in the Scientific Research, Technical Services and Geological Exploration from 2006 to 2018

From 2006 to 2018, the TFP growth rate of scientific research, technical services and geological exploration initially fluctuated at a first high level and then low level. Specifically, the growth rate of TFP increased greatly to about 10% in 2007, and then fluctuated continuously in the range of 5-10%. From 2012 to 2014, the growth rate of TFP declined sharply, falling to the valley of about -5% in 2014, and then the range of the swing slowed down, rising back to about 4% in 2018.

14. Water conservancy, environmental and public facilities management

From 2006 to 2018, the TFP growth rate of water conservancy, environmental and public facilities management fluctuated to rise as a whole. In 2006, growth rate began to increase from the valley, which was -20%, reaching the peak of about 5% in 2018.

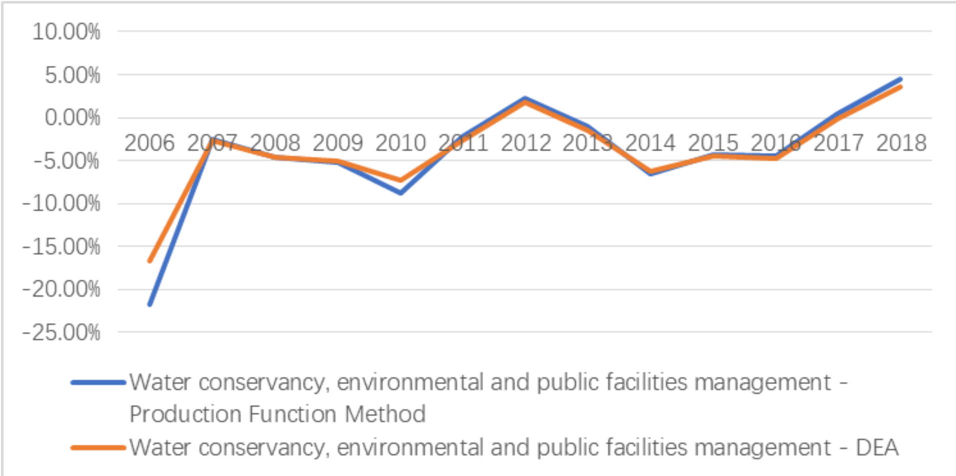

Figure 22 Growth Rate of TFP in the Water Conservancy, Environmental and Public Facilities Management from 2006 to 2018

15. Neighborhood services and other services

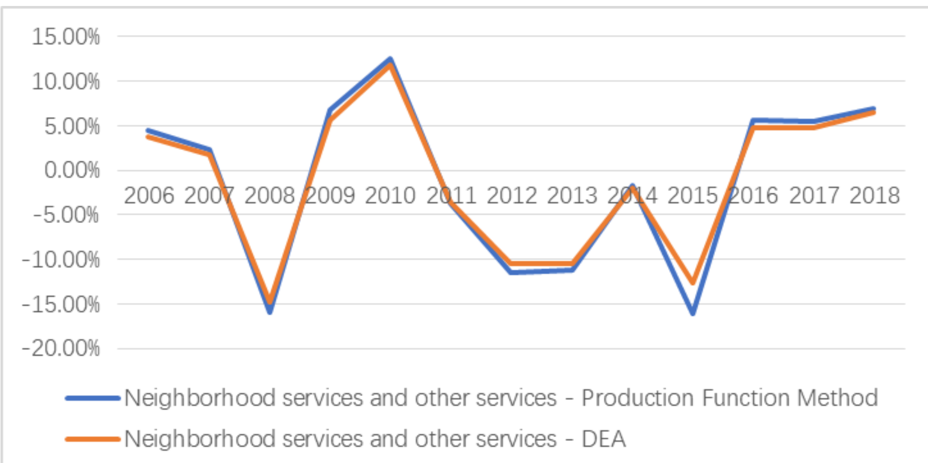

Figure 23 Growth Rate of TFP in the Neighborhood Services and Other Services from 2006 to 2018

From 2006 to 2018, the growth rate of TFP in neighborhood services and other services showed heavy swings. But in recent years, the fluctuation has slowed down.

In 2010, the growth rate of TFP initially reached the peak of the sample period, which was about 12%, and then declined to the valley of -16% in 2015, and experienced a long period of negative growth. Since 2016, the growth rate of TFP has risen sharply, changing from negative growth to positive growth, and increased to about 7% in 2018.

16. Education

The TFP growth rate of education from 2006 to 2018 has two valleys in the sample period, which were -13% in 2008 and -14% in 2015. After the two valleys, the growth rates all rapidly rebounded to a high point, and then swung to fall. There was a slight rebound in 2018 compared with 2017, with a growth rate of about 2%.

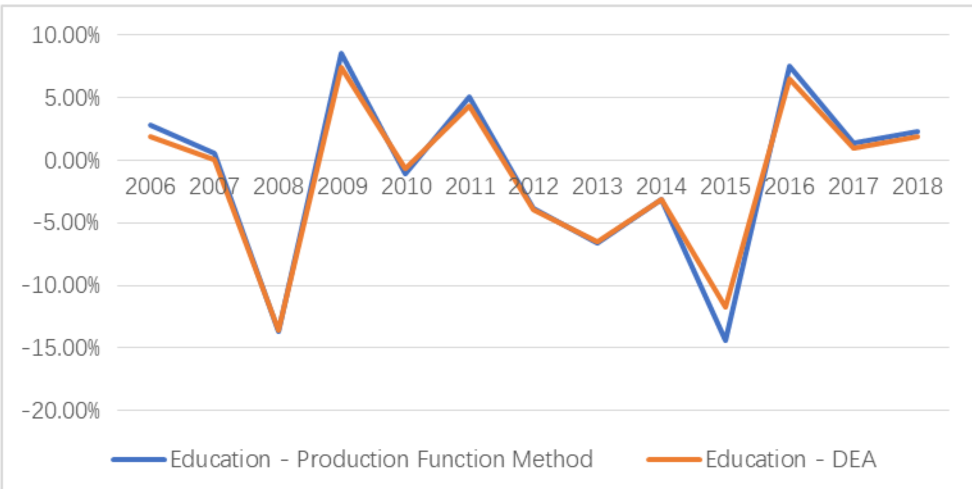

Figure 24 Growth Rate of TFP in the Education from 2006 to 2018

17. Health, social security, and social welfare

Figure 25 Growth Rate of TFP in the Health, Social Security and Social Welfare Industry from 2006 to 2018

The growth rate of TFP in health, social security and social welfare industries showed two regular changes from 2006 to 2018, which were stable initially, then declined and then increased rapidly. Similar patterns were observed in 2006-2012 and 2012-2018. In 2018, it rose sharply to over 22% compared with 2017.

18. Culture, sports and entertainment industry

From 2006 to 2018, the growth rate of TFP in culture, sports and entertainment industries showed a trend of continuous fluctuation, with the rate falling to a valley of -30% in 2011 and rapidly rebounded to a positive value in 2012. Compared with the negative value in 2017, 2018 has seen a rebound and a change from negative to positive.

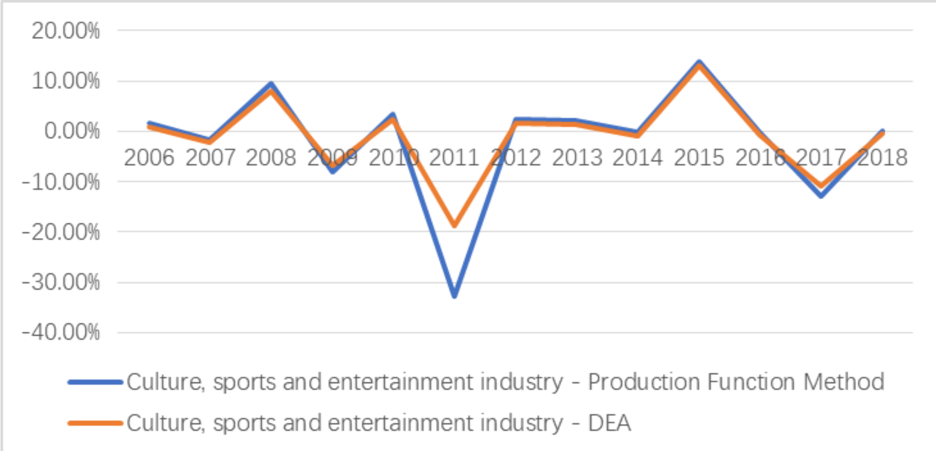

Figure 26 Growth Rate of TFP in the Culture, Sports and Entertainment Industry from 2006 to 2018

19. Public administration and social organizations

Figure 27 Growth Rate of TFP in the Public Administration and Social Organizations from 2006 to 2018

From 2006 to 2018, the TFP growth rate of public administration and social organizations showed two phases as a whole. The first phase is 2006-2011, in which the TFP growth rate fluctuated greatly, reaching a peak of about 30% in the sample period in 2010. The second phase is 2011-2018, in which the TFP growth rate fluctuated relatively slowly, showing an upward trend as a whole. In 2017, after the falling, the growth rate of TFP has returned to the level of about 9% in 2018.

iii. Comparative analysis of industries

Table 1 Average Annual Growth Rate of TFP in Different Industries with Different Phases

Industries	2006-2018	"The 11th Five-Year Plan"	"The 12th Five-Year Plan"	Since "the 13th Five-Year Plan"
Agriculture, forestry, animal husbandry, and fishery	-0.53%	1.50%	-1.51%	-0.77%
Mining industry	-3.01%	-4.92%	-4.69%	2.23%
Manufacturing	1.13%	0.35%	0.39%	2.98%
Production and supply of electricity, gas and water	-0.18%	1.61%	-5.05%	6.29%
Construction	2.11%	3.21%	0.00%	2.55%
Transportation, storage and postal industry	-0.21%	-4.00%	-0.46%	2.31%
Information transmission, computer service, and software	9.04%	0.57%	15.90%	11.26%
Wholesale and retail trade	3.20%	7.24%	-1.49%	3.00%
Accommodation and catering	-0.56%	0.89%	-5.20%	3.33%
Finance	3.62%	11.15%	6.60%	2.18%
Real estate	-6.71%	-12.64%	-6.62%	-2.43%
Leasing and business service industry	0.40%	1.37%	1.79%	-0.75%
Scientific research, technical service, and geological exploration	3.41%	8.54%	1.34%	0.48%
Water conservancy, environmental and public facilities management	-2.79%	-5.34%	-2.47%	2.43%
Neighborhood services and other services	-2.16%	0.85%	-10.24%	6.17%
Education	-1.71%	-1.74%	-7.13%	1.88%
Health, social security, and social welfare	-0.99%	-2.21%	2.63%	6.63%
Culture, sports and entertainment industry	-2.77%	0.54%	4.46%	-6.56%
Public administration and social organizations	1.06%	4.66%	-0.12%	0.75%

From the whole sample period of 2006-2018, the industries with positive annual growth rate of TFP (in descending order) include information transmission, computer services and software industry, finance, scientific research, technical services and geological exploration, wholesale and retail trade, construction industry, manufacturing industry, public management and social organizations, as well as leasing and business service industry. The industries with negative annual growth rate of TFP (in ascending order) include real estate industry, mining industry, water conservancy, environmental and public facilities management, culture, sports and entertainment, neighborhood services and other services, education, health, social security and social welfare, accommodation and catering industry, agriculture, forestry, animal husbandry and fishery, transportation, storage and postal industry, and production and supply of electricity, gas and water. Overall, the average annual growth rate of TFP in information transmission, computer services and software industry is significantly higher than that of other industries, reaching 9.04%. The finance, scientific research, technical services and geological exploration, wholesale and retail trade and construction industry are in the second echelon, with TFP growing at an average annual rate of 2% to 3%. Average annual growth rate of TFP in the education, neighborhood services and other services, culture, sports and entertainment industry and mining industry is between -2% and -3%. The average annual growth rate of TFP in real estate industry is the lowest, recording -6.71%.

During the whole sample period from 2006 to 2018, the growth rate of TFP in different industries is quite different. TFP of producer services such as information transmission, computer services and software industry, finance, scientific research, technical services and geological exploration industry, wholesale and retail trade has witnessed a fast growth, while TFP of life service industry and social service industry grew slower. Within the secondary industry, the growth rate of TFP in the construction and manufacturing industries grew faster than that in the production and supply of electricity, gas and water, and mining industry.

Since the 13th Five-Year Plan, except for information transmission, computer services and software industry, finance, leasing and business service industry, scientific research, technical services and geological exploration industry, as well as culture, sports and entertainment, the growth rate of TFP in other industries has increased significantly compared with that in the 12th Five-Year Plan period, among which neighborhood services and other services, production and supply of electricity, gas and water, education, and accommodation and catering industry had higher extent of increasing in TFP. Horizontally, since the 13th Five-Year Plan, the average annual growth rate of TFP in information transmission, computer services and software industry is still significantly ahead of other industries, as high as 11.26%. Health, social security and social welfare, production and supply of electricity, gas and water, neighborhood services and other services are in the second echelon, and the average annual growth rate of TFP is over 6%. The average annual growth rate of TFP in accommodation and catering industry, manufacturing industry and construction industry is about 3%. The average annual growth rate of TFP in leasing and business services, agriculture, forestry, animal husbandry and fishery, real estate industry, culture, sports and entertainment is negative.

The above analysis demonstrated that, since the "13th Five-Year Plan", the contribution of structural adjustment among industries to the growth of TFP increased gradually. The efficiency of resource allocation within the secondary industry was optimized to allow TFP to grow. The increase in TFP of producer service industry greatly supported the increase in TFP of the whole service industry. With the improvement of people's living standards, the growth of commodity consumption has dropped gradually. The proportions of enjoyment- and development-oriented consumptions have been increasing. The TFPs of some industries in life and public service industries have risen significantly.

VI. Analysis and Forecast of China's Potential Growth Rate

The definition of potential output is primarily based on two theories. According to Keynesianism, the utilization efficiency of a country's resources is different by economic cycle. Resources may be left unused or overused. Potential output stands for the output when all the resources are effectively utilized. Samuelson (1948) referred to natural growth rate as potential growth rate, which is the growth rate that the economy can achieve when all the input factors are fully utilized. Okun (1965) and Blanchard (1989) argued that, potential output cannot be equated with the maximum output that the economic society can produce and should be associated with employment and inflation. When both output and employment are at a high level, inflation will rise rapidly as well. Instead, when unemployment rate is high, inflation will fall. Therefore, potential output should be the growth rate when the natural unemployment rate is reached and does not lead to inflation, or Non-accelerating Inflation Rate of Unemployment (NAIRU).

In terms of neoclassical theories, the impact of productivity on the aggregate supply determines long-term economic growth and short-term economic fluctuation in the economic cycle. The fluctuation of economic cycle is not affected by the aggregate demand and policies. Neoclassical theories hold that, only unanticipated shocks can cause fluctuations in output. The actual GDP is divided into two parts, namely, the part whose long-term trend is persistence and the periodic part determined by temporary and unanticipated shocks.

In accordance with domestic and international researches, the calculation methods of potential growth rate can mainly be classified into two categories: The trend decomposition method and the production function method. The trend decomposition method mainly smoothens the actual output data. It decomposes GDP sequence into the trend part and the fluctuation part by means of measurement. The first part is potential output.

The production function method measures the future economic growth by predicting capital stock, human capital, and TFP, which is simple, intuitive, and common. It is necessary to predict each factor input, before applying the production function method to predict GDP. In regard to capital stock, the research team predicted China's capital stock in the next five years based on international comparison. From the perspective of GDP per capita, the research team estimated that, China's GDP per capita in 2018 as calculated based on purchasing power parity (PPP) would be approximately 16,000 international dollars. By exploring the growth rate of capital stock of latecoming economies that have successfully caught up with the leading economies and are at the same development level, the research team found that, the capital stocks of Japan, South Korea, and Hong Kong, China fell in the development period. And the averages in five years earlier and five years later are similar. The interval is 1.14-1.34. This paper referred to the comparison of averages in five years earlier and five years later of Japan, South Korea, and Hong Kong, China to predict that, the growth of capital stock of China in the next five years will be roughly be around 8-9%. As shown in the figure below, when GDP per capita reaches 16,000 international dollars, the growth rates of capital stocks of Japan and South Korea had a downward trend. In addition, it is necessary to consider China's own situation to judge the fluctuation of short-term capital stock. In 2018, China's fixed asset investment stabilized and rebounded. In 2019, fixed asset investment will continue to rise, however, at a small growth rate. The short slab will be made up primarily. Hence, it is expected that, the investment will rebound slightly in 2019. In general, the growth rate of capital stock in the next five years will generally decline, but that in the next two years may increase slightly.

Table 2 Comparison of growth rate of capital stock

Economies	**Year**	**GDP per capita (PPP International Dollar)**	**Average in the Previous 5 Years**	**Average in the Future 5 Years**	**Difference between the Averages**	**Ratio of the Average**
China	2018	16078	10.53%	8.08%	2.03%	1.30
Japan	1977	16141	16.29%	14.24%	2.05%	1.14
South Korea	1993	15691	13.03%	9.98%	3.05%	1.31
Hong Kong, China	1982	15993	9.46%	7.07%	2.40%	1.34

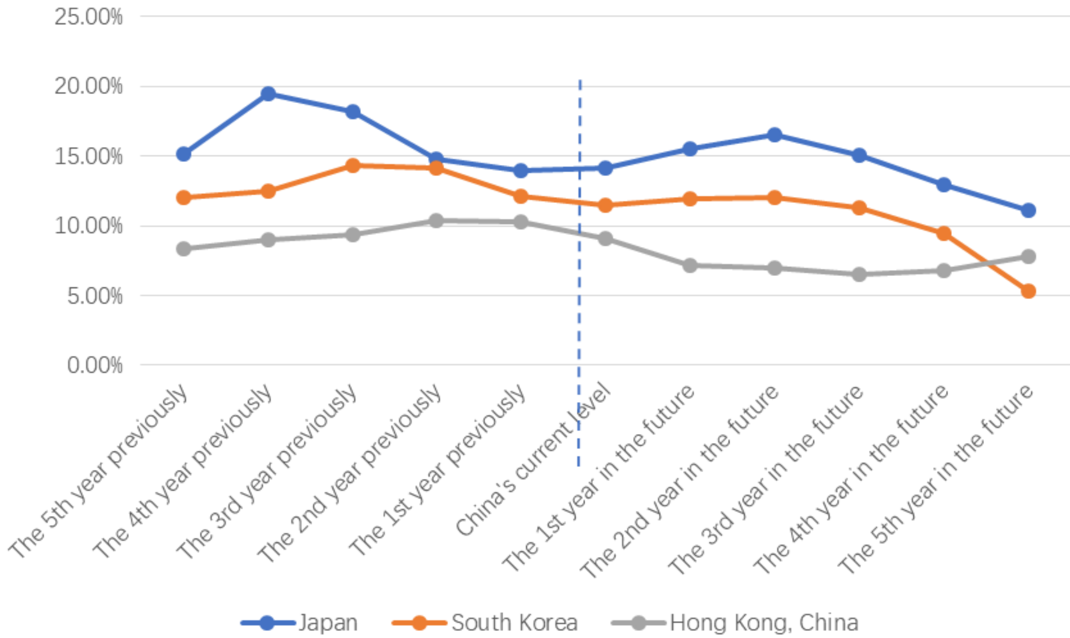

Figure 28 Changes in the Growth Rate of Capital Stock Near the GDP per capita of 16,000 International Dollars

The number of employed people in the next five years is expected to show a negative growth trend. The forecast of employment in this paper referred to the research of He Jianwu (2018). There are many researches predicting China's future TFP. Most of them set the growth of TFP as a fixed value or as three values, that is, high, medium, and low values for scenario simulation. As FTP is a complex parameter related to multiple factors like technological progress, scale effect, and institutional reform. As the scale of economy continues to expand, the growth rate of TFP will gradually stabilize. The forecast for TFP growth in the next five years is based on the moving average of TFP growth in the past five years (Sheng Laiyun et al., 2018). It can be seen from the results that, the growth of TFP will slowly rise in the next five years. And the average will remain at around 3.13%. Additionally, in the production function equation, the data in 2018 are applied to the share of income from labor and the share of income from capital in the next five years, mainly because the time-varying shares of income from labor and capital in the past five years remained at about 62% and 38% which were stable. Lastly, the prediction results are based on the potential growth rates in the next five years obtained from the production function equation, as shown in Table 3:

Table 3 Predicted potential growth rates from 2019 to 2023

Year	Growth of Capital Stock	Growth of Employment	TFP	Potential Growth
2019	8.80%	-0.20%	3.03%	6.25%
2020	8.90%	-0.10%	3.08%	6.40%
2021	7.90%	-0.10%	3.17%	6.11%
2022	7.50%	-0.20%	3.20%	5.93%
2023	7.30%	-0.20%	3.17%	5.82%

We can see that, the potential growth rates in the next five years will gradually slow down. In 2019, it will continue to decline to around 6.25%. It is expected that, by 2023, the potential growth rate will drop to around 5.82%.

There are many researches on future TFP growth and potential productivity. Table 4 summarizes the predicted TFP and potential growth by some representative institutions and relevant researchers. Overall, according to the research results, the average annual TFP growth rates are between 1.4% and 3.5%. The average of predicted values in the next five years by the research team is approximately 3.13%. With respect to potential growth rate, several research results indicated that, the potential growth rates before 2020 is expected to be between 5% and 7.3%. It will decline in 2020, which is basically consistent with the prediction of the research team. The average in the next five years predicted by the research team is around 5.7%.

Table 4 Summary of predicted TFPs and annual average potential growth rates by representative researches

Representative Literature	Estimation Duration	Annual Average TFP Growth Rate	Annual Average Growth Rate	Method
Lu Yang and Cai Fang (2016)	2016-2020	2.37%	6.65%	Production Function Method
	2021-2025	2.37%	5.77%	
World Bank, the research team of Development Research Center of the State Council (2013)	2016-2020	2%	7%	CGE Method
	2021-2025	2%	5.90%	
	2026-2030	2%	5%	
Institute of Economic Chinese Academy of Social Sciences (2012)	2016-2020	2%	6.6-5.7%	Production Function Method
	2021-2030	2.50%	5.4-6.3%	
National Bureau of Statistics of China: Sheng Laiyun et al. (2018)	2018-2020	1.4-2.3%	6.0-4.5%	Production Function Method
	2021-2035	2.4-3.9%		
The research team of Bank of China (2016)	2019-2020	1.8-3%	5.9-7.3%	Production Function Method
	2021-2025	1.8-3%	5.3-6.6%	
Institute of Research of National Development and Reform Commission: Yi Xin and Guo Chunli (2018)	2020	2-3%	5.5-7.3%	Production Function Method
	2021-2025	2-3%	4.7-6.2%	
OECD（2012）	2019-2020	3.50%	6.16%	Production Function Method

VII. Policy Recommendations

In accordance with the prediction of this paper, China's economy in the next five years will gradually stabilize and grow at a medium rate. Infrastructure, real estate, and export demands, driving fast economic growth in the past, have implemented. The decline in growth of capital stock and the disappear of demographic dividend will lead to further slowdown in growth rate. International experience implied that, TFP will gradually take over the investment whose growth slows down and become the main driving force to constant economic growth in this period. Thanks to relevant measures like the supply-side structural reform, the TFP in the "13th Five-Year Plan" period has shown an apparent turning point. It has grown from a decline. Thus, China's productivity will have promising potential growth. In the overall background of comprehensive deepening of reform, we must endeavor to break administrative monopolies, create a level playing field, transform governmental functions, optimize capital allocation, protect intellectual property right, release the potential for productivity improvement, and develop China's new economic growth momentum. The specific recommendations are as follows:

First of all, improve the low-efficient departments and improve the allocative efficiency of factors within the industry. As capital and labor transfer from agriculture to manufacturing and services industries, the room for improvement of inter-industry allocative efficiency of factors has been gradually decreased. However, the marginal output still has large differences among different industries and even enterprises. Especially in basic industries such as energy, logistics, communications, finance, and land, the problem of administrative monopoly stands out, leading to high costs and insufficient competition abilities of enterprises, and then seriously affecting the production efficiency. Therefore, it is the key way to eliminate misallocation of production resources among enterprises of different industries, different types, and in different regions, in order to improve the total factor productivity of manufacturing and service industries in the future. On the one hand, it is urgent to break administrative monopoly and reduce costs. On the other hand, it is important to improve the competition and exit mechanisms of enterprises, and free up social resources occupied by zombie enterprises to improve allocation efficiency.

Second, promote the upgrading of consumption structure and industrial structure. The consumption need of the middle-income group has been basically met, and its growth rate will decline gradually. To promote the upgrading of consumption structure and change the basic needs from a concentration on quantity to quality, it needs to raise the proportion of enjoyment-oriented and development-oriented consumption, including medical care, education, culture, sports, entertainment, care for the aged, and tourism to form a new growth point. At the same time, accelerate the adjustment of government fiscal expenditure structure, improving proportion of the expenditure on education, health, social security and welfare, in which fields the government and residents expenditure should be well balanced.

Third, speed up the development and opening up of knowledge intensive services. The knowledge intensive services industry has high intensity of knowledge, including producer services such as research and development, design, information services, logistics and consulting, and social and personal services such as medical care and health, education, culture, sports, and entertainment. The knowledge intensive services are the focus for further development of services industry. Through optimizing the allocation of resources, it is likely to generate higher productivity with huge development space and potential. There are certain gaps between the knowledge intensive services industry in our country and those in the developed countries. Thus, it needs to force opening up internally by opening up to the outside world, and broaden access of high-level research and development of education and other knowledge intensive services. Introduce more human capital of high quality to these areas, and promote the knowledge intensive services to become important impetus of transformation and upgrading of economy.

Fourth, improve the human capital. Due to an aging population, the declining trend of both China's working age population and employment population is inevitable. As a result, to improve human capital, especially the human capital of the vulnerable, is advantageous to decrease the negative effect to economic growth brought by declining demographic dividend. In order to improve human capital, it needs to create and maintain the environment of equal development of human capital. Compulsory education should be universal, and vocational training should be provided in the context of structural adjustment and technological progress. Social security system should be improved including care for the aged, medical care and employment, so that social members are free from the fear of uncertainties brought by personal safety, employment and technological progress. Population mobility should be promoted in an all-round way, especially in breaking down class solidification. Vertical mobility should be paid more attention to while promoting horizontal mobility.

Fifth, accelerate frontier innovation. China has the world's largest market in frontier innovation including the Internet, big data, and artificial intelligence. It has good industrial supporting conditions, and has started to lead in some areas in terms of technology. However, there are still shortcomings in basic research and institutional mechanisms. The key to consolidate and future develop frontier innovation is to improve the level of higher education and basic research. Efforts should be made to strengthen the protection of intellectual property rights, accelerate breakthroughs in basic research while legally introducing technologies, and promote independent innovation. At the same time, we should boldly explore the system and mode of higher education in areas where innovation is active. For example, some high-level educational R&D centers could be established, giving special mechanisms and policies in enrollment, employment, project management, fund raising, intellectual property, nationalities, etc. for greater freedom of choices and trial and error. This is to foster an environment that suits China's national conditions, absorbs advanced practices in the world, and maximizes people's creativities at the frontier of scientific discovery and technological innovation.

VIII. Bibliography

蔡昉,都阳.“文化大革命”对物质资本和人力资本的破坏[J].经济学(季刊),2003(03):795-806.

蔡昉.人口转变、人口红利与刘易斯转折点[J].经济研究,2010,45(04):4-13.

蔡跃洲，付一夫.全要素生产率增长中的技术效应与结构效应——基于中国宏观和产业数据的测算及分解[J].经济研究，2017，52(01):72-88

董敏杰，梁泳梅.1978—2010 年的中国经济增长来源:一个非参数分解框架[J].经济研究，2013.

刘世锦、张军扩、侯永志和刘培林，陷阱还是高墙：中国经济面临的真实挑战与战略选择，比较，2011(03):11-17

刘世锦，刘培林，何建武.我国未来生产率提升潜力与经济增长前景[J].管理世界，2015(03):1-5.

刘世锦.中国经济的“要害问题”[J].商业观察，2018(09):13-17.

刘世锦.优先推动与高质量发展配套的改革[J].中国中小企业，2018(10):57-60.

刘世锦. 尽快实现转型再平衡需要一些重要条件[N]. 北京日报,2015-03-30(017).

刘世锦等，2011：《陷阱还是高墙：中国经济面临的真实挑战和战略选择》，中信出版社:

刘伟，李绍荣.所有制变化与经济增长和要素效率提升[J].经济研究，2001(01):3-9+93.

刘伟，张立元.资源配置、产业结构与全要素生产率:基于真实经济周期模型的分析[J].经济理论与经济管理，2018(09):5-22.

刘伟、张辉.中国产业结构变迁及劳动生产率增长[J].经济研究，2008(11)

林毅夫，刘培林.经济发展战略对劳均资本积累和技术进步的影响——基于中国经验的实证研究[J].中国社会科学，2003(4):18-32.

林毅夫，任若恩. 东亚经济增长模式相关争论的再探讨[J].经济研究，2007(08):4-12+57

刘舜佳. 国际贸易、FDI 和中国全要素生产率下降——基于 1952～2006 年面板数据的 DEA 和协整检验[J].数量经济技术经济研究，2008，25(11):28-39+55.

鲁晓东，连玉君.中国工业企业全要素生产率估计:1999—2007[J].经济学(季刊)，2012，11(2):541-558.

陆旸,蔡昉.从人口红利到改革红利:基于中国潜在增长率的模拟[J].世界经济,2016,39(01):3-23.

林春，孙英杰.财政失衡与全要素生产率损失:中国的证据[J].云南财经大学学报，2019，35(01):3-14.

平新乔，黄昕，安然.“营改增”前中国服务业与制造业之间全要素生产率的异质性和税负差异[J].经济社会体制比较，2017(02):77-84.

舒元.中国经济增长的国际比较[J].世界经济，1993(6):29-34.

盛来运,李拓,毛盛勇,付凌晖.中国全要素生产率测算与经济增长前景预测[J].统计与信息论坛,2018,33(12):3-11.

王小鲁，樊纲，刘鹏.中国经济增长方式转换和增长可持续性[J].经济研究，2009(1):44-47.

吴友群，王立勇，廖信林.对中国 2012 年经济增长率预测准确性的评析[J].经济学动态，2013(02):33-38.

王维，陈杰，毛盛勇.基于十大分类的中国资本存量重估:1978～2016 年[J].数量经济技术经济研究，2017，34(10):60-77.

姚洋，章奇.中国工业企业技术效率分析[J].经济研究，2001(10):13-19.

叶裕民.全国及各省区市全要素生产率的计算和分析[J].经济学家，2002，3(3):115-121.

易纲，樊纲，李岩.关于中国经济增长与全要素生产率的理论思考[J].经济研究，2003(08):13-20+90.

杨建芳，龚六堂，张庆华.人力资本形成及其对经济增长的影响——一个包含教育和健康投入的内生增长模型及其检验[J].管理世界，2006(5):10-18.

姚战琪.生产率增长与要素再配置效应:中国的经验研究[J].经济研究，2009(11):130-143.

郑玉歆.全要素生产率的测度及经济增长方式的“阶段性”规律——由东亚经济增长方式的争论谈起[J].经济研究，1999(05):57-62.

张军.资本形成、工业化与经济增长:中国的转轨特征[J].经济研究，2002(6):3-13.

张军，施少华.中国经济全要素生产率变动:1952-1998[J].世界经济文汇，2003(2):17-24.

郑京海，胡鞍钢.中国改革时期省际生产率增长变化的实证分析(1979—2001 年)[J].经济学(季刊)，2005，4(1):263-296.

章艳红.中国贸易结构的变化特点、决定要素以及政策建议[J].国际贸易，2007(10):4-9.

章祥荪，中国全要素生产率分析:Malmquist 指数法评述与应用[J].数量经济技术经济研究，2008，25(6):111-122.

中国经济增长前沿课题组,张平,刘霞辉,袁富华,陈昌兵,陆明涛.中国经济长期增长路径、效率与潜在增长水平[J].经济研究,2012,47(11):4-17+75.

中国银行"中国经济发展新模式研究"课题组,陈卫东,宗良.中国经济潜在增长率的估算与预测——新常态新在哪儿[J].金融监管研究,2016(08):41-66.

伍晓鹰，2013：“测算和解读中国工业的全要素生产率”,《比较》，第 6 期

何建武，2014：“全要素生产率：持续改善配置结构” 载于刘世锦主编，《中国经济增长十年展望（2014-2023）：在改革中形成增长新常态》，中信出版社

郭晗，任保平. 结构变动、要素产出弹性与中国潜在经济增长率[J]. 数量经济技术经济研究, 2014(12):72-84.

Bosworth B, Collins S M. United States-China trade: where are the exports?[J]. Journal of Chinese Economic & Business Studies, 2008, 6(1):1-21.

Battese G E, Coelli T J. A model for technical inefficiency effects in a stochastic frontier production function for panel data[J]. Empirical Economics, 1995, 20(2):325-332.

Coelli, T. APPENDIX 1 : COMPUTER SOFTWARE DEAP Version 2 . 1 : A Data Envelopment Analysis (Computer) Program. An Introduction to Efficiency and Productivity Analysis, 2005, 317–324.

Charnes A, Cooper W W, Rhodes E. Evaluating Program and Managerial Efficiency: An Application of Data Envelopment Analysis to Program Follow Through[J]. Management Science, 1981, 27(6):668-697.

Gregory C. Chow, Kui-Wai Li. China’s Economic Growth: 1952–2010[J]. Economic Development & Cultural Change, 2002, 51(1):247-256.

Jr, Robert E. Lucas, . "On the Mechanics of Economic Development." Quantitative Macroeconomics Working Papers 22.1(1999):3-42.

Krugman P. The Myth of Asia's Miracle[J]. Foreign Affairs, 1994, 73(6):62-78.

Kuznets S. International Differences in Capital Formation and Financing[J]. Numerical Heat Transfer Part A Applications, 1955, 48(8):763-790.

Mankiw, N. Gregory, David Romer, and David N. Weil, “A Contribution to the Empirics of Economic Growth”, Quarterly Journal of Economics, 107, May 1992, 407-37.

Maddison A. Chinese Economic Performance in the Long Run[M]// Chinese economic performance in the long run /. 1998.

Nelson, R. R. , & Phelps, E. S. . (1966). Investment in humans, technological diffusion and economic growth. Cowles Foundation Discussion Papers, 56(1/2), 69-75.

Stigler G J. Stuart Wood and the Marginal Productivity Theory[J]. Quarterly Journal of Economics, 1947, 61(4):640-649.

Solow R M. TECHNICAL CHANGE AND THE AGGREGATE PRODUCTION FUNCTION[J]. Review of Economics & Statistics, 1957, 39(3):554-562.

Tinbergen J . Critical Remarks on Some Business Cycle Theories[J]. Econometrica, 1942, vol. X(2):129-146.

Wang Y, Yao Y. Sources of China's economic growth 1952–1999: incorporating human capital accumulation[J]. China Economic Review, 2003, 14(1):32-52.

Yanrui Wu. Service Sector Growth in China and India: A Comparison[J]. Economics Discussion, 2007, 5(1):137-154.

Young A. Growth Without Scale Effects[J]. Nber Working Papers, 1995, 106(1):41-63.