Research on Total Factor Productivity in China's Economic Growth Since the Reform and Opening-up

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Abstract. Total Factor Productivity (TFP) is an important driver of economic growth and a key indicator for measuring the quality of economic growth. This study utilizes Chinese statistical data and employs the Solow residual method to calculate China's TFP. The research reveals that between 1978 and 2022, China's TFP experienced a growth rate of 2.73%, contributing 29.49% to economic growth. However, the level of TFP still needs improvement. Particularly in the last 10 years, China's TFP growth rate has displayed a slow upward trend, and the optimization effect of economic structure has not been significant. Based on these findings, it is suggested that in the new era of China's development, comprehensive deepening of reforms should be continued, the development of an open economy should be steadfastly pursued, and efforts to promote technological innovation should be continuously made in order to shift China's economic growth towards a TFP driven model.

Keywords: reform and opening-up, total factor productivity, innovation-driven

1 Introduction

Understanding total factor productivity (TFP) is crucial for studying the issue of economic growth. Since the reform and opening-up, the Chinese economy has experienced long-term high-growth, achieving remarkable social and economic development. According to the new growth theory, economic growth is primarily driven by factor inputs and TFP. Relying solely on expanding factor inputs to increase output, without considering the consequences of excessive resource consumption and pollution, is an unsustainable growth model. Only by increasing the contribution of TFP can the level of economic development and sustainable development capabilities be enhanced. This is especially significant in the current context of domestic and international dual circulation development, where continuous improvement in TFP contribution is necessary. Shifting away from a factor-driven growth model to one that relies on technological progress and efficiency improvement is not only due to the previous extensive economic development model is unsustainable, but also a necessary requirement for entering a new era of economic development. Starting from 2013, China's GDP growth rate has been decreasing rapidly, with an average annual growth rate of only 8.43% from 2013 to 2022, indicating a structural deceleration in economic growth. Therefore, it is necessary to further analyze and study the factors of China's economic growth and the effects of economic structural optimization.

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TFP, as an important concept in macroeconomics, is a crucial tool for analyzing the drivers of economic growth [1]. In 1957, Solow first incorporated technological progress into the economic growth model, categorizing the factors driving economic growth into broad-based technological progress, fixed capital stock, and labor [2]. Among them, broad-based technological progress is attributed to the rate of technological progress, known as the Solow residual, which later became known as the growth rate of TFP. Currently, domestic scholars have conducted extensive research on China's economic growth, assessing the contributions of various factors to economic growth[3], [4], [5]. The calculations are mainly based on the new economic growth theory, which expresses TFP as the residual value of output growth after excluding factor input contributions. Existing research mainly focuses on measuring capital [6], calculating labor force, and methods for measuring labor share [7], [8], [9].

International authoritative institutions also differ in the process of calculating TFP. For example, the Bureau of Labor Statistics, the Bureau of Economic Analysis, the Organization for Economic Cooperation and Development, and other departments show significant differences in the coverage of indicators, processing methods, and determination of capital depreciation rates when calculating TFP. This study will integrate the practices of authoritative institutions and fully consider China's special national conditions to scientifically measure the TFP of China's economic growth. The aim is to reveal the contribution of TFP to economic growth, which is not only of great theoretical and practical significance for understanding China's economic progress but also provides valuable experience for other developing countries to learn from.

2 Model construction and indicator selection

2.1 Model Construction

This study employs the Solow Residual method to calculate TFP, which is a method that is clear, simple, and easy to operate, and has been widely used by scholars both domestically and internationally. The basic idea is to deduct the contributions of factors and labor from the economic growth rate after estimating the aggregate production function. Assuming neutral technological progress, the TFP growth rate is equal to the rate of technological progress. The calculation of the Solow Residual relies on the production function, and the Cobb-Douglas production function is more suitable for the economic growth situation in China [10]. This study also adopts the Cobb-Douglas production function to describe the economic growth situation in China, as shown in Equation (1).

$$Y_t = A_0 e^{rt} K_t^{\alpha} L_t^{\beta} e^{\mu} \ (t = 1, 2, \cdots, n) \qquad (1)$$

In Equation (1), Y_t represents the output in China during t period; $A_0 e^{rt}$ represents the technological level during t period, which indicates that the initial technological level A_0 changes year-by-year under the assumption of a technological progress level of r (r is a constant); K_t represents the capital input in China during t period; L_t represents the labor input in China during t period; α and β represent the elasticity of capital output and labor output, respectively; μ represents the random error term. Typically, it is assumed that $\alpha + \beta = 1$, which means that the production function exhibits constant returns to scale.

Taking the logarithm of Equation (1), we have:

$$\ln(Y_t) = ln(A_0) + rt + \alpha ln(K_t) + \beta ln(L_t) + \mu \qquad (2)$$

Assuming constant returns to scale in the production function, Equation (2) can be transformed into:

$$\ln(Y_t/L_t) = ln(A_0) + rt + \alpha ln(K_t/L_t) + \varepsilon_t (3)$$

Let $y_t = ln(Y_t/L_t)$, $c = ln(A_0)$, $k_t = ln(K_t/L_t)$, then we have:

$$y_t = c + rt + \alpha K_t + \varepsilon_t \quad (4)$$

According to the Solow Residual formula:

$$\frac{dA_t}{A_t} = \frac{dY_t}{Y_t} - \sum_{n=1}^{N} \delta_n (\frac{dx_{n,t}}{x_{n,t}}) (5)$$

Equation (4) can be converted into:

$$\frac{dA_t}{A_t} = \frac{dY_t}{Y_t} - \alpha \frac{dK_t}{K_t} - \beta \frac{dL_t}{L_t} \quad (6)$$

Where $\frac{dA_t}{A_t}$ represents the growth rate of TFP, $\frac{dY_t}{Y_t}$, $\frac{dK_t}{K_t}$, and $\frac{dL_t}{L_t}$ represent the growth rates of output, capital input, and labor input, respectively.

2.2 Indicator Selection

In the process of measuring TFP growth in China, to ensure the accuracy of data measurement, publicly available data published by the National Bureau of Statistics are selected. Additionally, the selection of indicators related to variables undergoes analysis and processing to ensure comparability of the analysis results. The following is the process of data selection and processing.

Output Y_t, which measures the overall output of the national economy, can be evaluated from the perspective of regional economic development scale and level. Gross Domestic Product (GDP) can measure the economic scale of a region, while per capita GDP can reflect the level of economic development. Output Y_t is represented by China's GDP from 1978 to 2022, and the nominal output is reduced using a deflator index and converted into actual values at constant prices of 1978.

Capital input K_t refers to the flow of capital services provided by the total capital stock that constitutes production capacity. Considering the availability of data, the capital stock is commonly used as a proxy for the flow variable. The estimation of capital stock is typically done using the perpetual inventory method (PIM) for fixed capital stock measurement [11]. This approach is also utilized in this study to estimate China's capital stock over the years. The specific formula is shown in Equation (7).

$$K_t = (1 - \delta)K_{t-1} + I_t/P_t \, (7)$$

In the formula, K_t and K_{t-1} represent the fixed capital stock in China during periods t and $t - 1$, respectively. δ denotes the fixed assets depreciation rate. I_t represents the nominal investment amount in China during period t, and P_t represents the price index of investment in fixed assets. For the investment amount I_t in a given year, total investment in fixed assets and gross fixed capital formation are commonly used in China. However, using the former may lead to an overestimation of the capital stock, so this study adopts gross fixed capital formation as the input I_t. As for P_t, the investment flows in different years are not comparable due to differences in investment goods prices. Therefore, a certain price index needs to be used to adjust for inflation and convert the nominal value into actual values based on a constant price level. In this case, the nominal investment amounts of China in each year are converted into actual values based on the 1978 price level.

Labor input L_t, is a measure of the service flow provided by labor during a certain period. Foreign scholars typically use labor time as a measurement [12], but in China, the relevant statistical data is incomplete. Domestic researchers commonly use the annual published number of employees in the entire society as a proxy variable for labor input, which can reasonably reflect the impact of labor input on economic growth. This method is based on the assumption of undifferentiated laborers, attributing any differences among laborers to technological progress.

3 Research on factor inputs and TFP in China's economic growth

3.1 Analysis of TFP Growth Rate in China's Economic Growth

Employing the aforementioned methodology, it is possible to calculate the TFP that better fits the China's conditions, and it becomes possible to generate a graphical representation, as depicted in Figure 1, illustrating the trend of TFP growth rates in China's economic development.

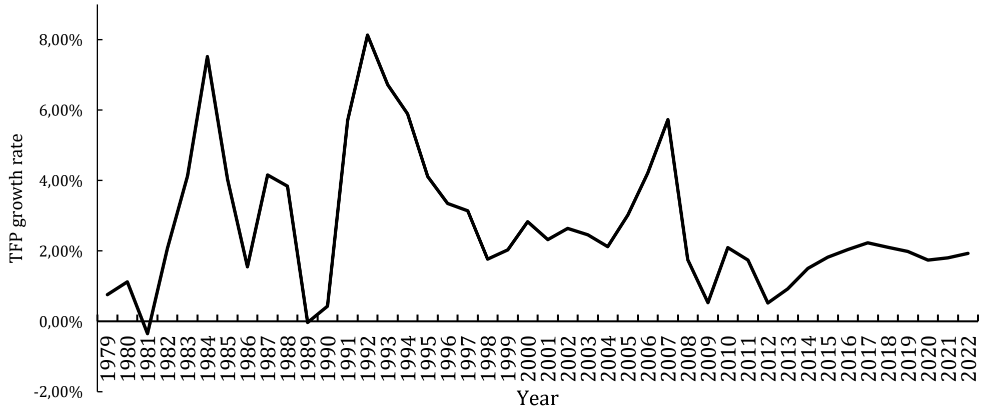

Figure 1: Growth rate of TFP in China's economic growth.

According to Figure 1, it can be seen that since 1978, China's economic growth has been closely linked to a series of institutional dividends, which have been transformed into actual economic output through the rapid growth of TFP. With the implementation of the household contract responsibility system with remuneration linked to output in rural areas at the beginning of China's reform and opening-up in 1978, the productivity of rural areas was greatly liberated, and the vitality of small-scale peasant economy was fully stimulated. This institutional reform directly contributed to a significant improvement in agricultural TFP. It not only improved the living standards of farmers but also released a large amount of surplus labor in rural areas, laying a solid foundation for subsequent urbanization and industrialization.

In 1992, Deng Xiaoping's Talks in the South reaffirmed the historical task of reform and opening-up, especially by proposing the goal of "establishing the socialist market economic system", which injected new powerful momentum into China's reform and opening-up. A series of measures such as state-owned enterprises reform, ownership reform, and financial system reform effectively improved resource allocation efficiency, accelerated the transformation of China's economic structure, and fundamentally promoted further growth of TFP. In 2001, with China's accession to the WTO, the opening-up entered a new phase. Foreign trade gradually became an important engine driving economic growth, and the significant increase in exports brought strong impetus to the economy. Simultaneously, a significant influx of foreign direct investment not only provided capital support but more importantly, introduced advanced technology and management methods, creating important opportunities for the upgrading and transformation of China's manufacturing and service industries, and significantly driving TFP growth.

However, it is worth noting that as these institutional dividends gradually diminish, the growth rate of TFP has started to slow down. During the global financial crisis in 2008, the Chinese government implemented four-trillion economic stimulus plan, which temporarily alleviated the downward pressure on the economy. However, the strategy of excessive reliance on capital investment also exposed the potential negative impact on TFP growth. In recent years, as China's economy has shifted towards a development model driven by coordinated consumption, investment, and exports, the growth pattern has also shifted from high-speed growth to high-quality growth. In this context, the role of TFP is once again emphasized. The government's implementation of policies such as innovation-driven development strategy and supply-side structural reform provides momentum and opportunity for the recovery of TFP.

In the future, with the deepening development of a new round of technological revolution and industrial transformation, the growth of TFP will rely more on the cultivation and release of new driving forces such as technological innovation, human capital improvement, and ecological environment protection. Through systematic reforms and structural adjustments, China will undoubtedly achieve more sustainable and balanced economic growth in the new era.

3.2 Contribution of TFP to China's Economic Growth

Throughout the more than 40-year history of China's economic development, the changes in TFP have mirrored the shift from pursuing speed to pursuing quality. Influenced by different degrees of openness to the outside world, marketization processes, and macroeconomic control policies, improving TFP remains the key to sustained and healthy growth of the economy in the future. Considering the national macroeconomic background, China's economic growth can be divided into five distinct periods, characterized by important milestones such as opening-up to the outside world, economic system reforms, accession to the WTO, financial crisis, and comprehensive deepening of reforms. The specific divisions are shown in Table 1.

Table 1: Contribution of TFP in different periods.

Period	GDP growth rate	Capital input	Labor input	TFP
1978-1992	15.35%	50.32%	13.27%	36.41%
1993-2000	18.20%	56.34%	5.36%	38.30%
2001-2007	15.28%	63.82%	2.65%	33.53%
2008-2012	14.88%	83.39%	1.76%	14.85%
2013-2022	8.43%	74.58%	1.08%	24.34%

The initial period (1978-1992): Reform and opening-up, and economic takeoff. During this time, the TFP contribution rate in China reached 36.41%, reflecting the release of tremendous economic potential in the early stages of reform and opening-up. Major policy adjustments, such as the household contract responsibility system with remuneration linked to output in rural areas, urban economic system reform, and the development of an export-oriented economy, greatly promoted productivity improvement and technological progress. Particularly, after the separation of ownership and use of means of production, enterprises and individuals, driven by their pursuit of increased income, became more focused on economic efficiency, which directly contributed to the improvement of TFP.

The second period (1993-2000): Deepening reforms and establishment of market economy system. During this period, the TFP contribution rate slightly increased to 38.30%. In the mid-1990s and onwards, China continued to deepen its reform efforts and successfully implemented the socialist market economy system. Through large-scale state-owned enterprise reforms, market competition mechanisms were introduced to optimize resource allocation. Simultaneously, a large influx of foreign investment brought in new management knowledge and technology, further enhancing productivity. Additionally, the preparations for joining the WTO provided new development opportunities for China's manufacturing and service industries.

The third period (2001-2007): WTO accession and global economic integration. After joining the WTO, China's TFP contribution rate was 33.53%, slightly lower than the previous phase. While China experienced rapid economic growth after joining the WTO, this growth was largely driven by the expansion of foreign trade and capital accumulation, leading to a relative decline in the share of TFP growth. During this period, China became known as the "world's factory," leveraging its labor force and cost advantages to occupy a crucial position in the global supply chain.

The fourth period (2008-2012): Economic stimulus amid the global financial crisis. During the global financial crisis in 2008 and its aftermath, China's TFP contribution rate experienced a significant decline, reaching its lowest point at 14.85% compared to the other periods. To counter the economic slowdown, the Chinese government implemented massive economic stimulus measures, particularly investing in infrastructure construction. Although these measures stabilized economic growth in the short term, they also intensified reliance on capital input and reduced the contribution of TFP growth.

The fifth period (2013-2022): Transformation, upgrading, and the new normal. During this period, China's TFP contribution rate rebounded to 24.34%, indicating that after a period of structural adjustment and economic transformation, the Chinese economy began to prioritize improving quality and efficiency. The Chinese government promoted supply-side structural reforms, emphasized innovation-driven development, vigorously developed strategic emerging industries, facilitated the upgrading of traditional industries, and guided sustainable economic development through environmental protection and energy consumption dual-control policies. These measures helped reduce ineffective and excess capacity, improve the overall efficiency of economic operations, and thus support TFP growth.

4 Conclusions

This study uses the Solow residual method to calculate China's TFP since the beginning of the reform and opening-up in 1978. The study finds that the growth rate of TFP has fluctuated significantly during the period of 1978 to 2022, and the current development trend is a slow upward trajectory. The remarkable economic expansion in China has predominantly been attributed to the dual drivers of capital accumulation and labor supply. However, the TFP growth has experienced a significant decline after the policy stimulus in 2008, and although it has gradually recovered in recent years, the growth rate has slowed down. In the long term, sustainable economic growth cannot solely rely on factor inputs. Currently, China is facing challenges such as weak manufacturing investment, declining investment returns, accelerated aging population, and the gradual disappearance of the demographic dividend. Therefore, the key to ensuring high-quality economic development in the future lies in improving the contribution of TFP. It is important to note that TFP does not entirely equate to technological progress, it can be further divided into the contribution of industrial structural changes brought about by market-oriented reforms and the contribution of pure technological advancements to economic growth. This study suggests that the following aspects can be focused on to improve TFP in the future.

Firstly, it is important to continue to comprehensively deepening reforms. Market-oriented reforms and urbanization can not only enhance TFP through better factor allocation and incentive mechanisms but also address long-standing structural issues in China. Currently, obstacles such as the rural-urban divide, restrictions on labor mobility due to the household registration system, and inadequate multi-level capital markets severely impede the full release of economic potential. In April 2020, the Chinese government issued the "Opinions on Building a More Perfect System and Mechanism for Market-based Allocation of Factors," aiming to remove obstacles to free factor mobility. This is an important step in market-oriented reforms. Through these reforms, it becomes feasible to encourage the unrestricted movement of production factors such as population, technology, land, capital, and data in a wider range of areas, thereby stimulating economic vitality, promoting optimal resource allocation, and enhancing production efficiency.

Secondly, it is crucial to steadfastly develop an open economy. This means not only actively expanding international engagements but also promoting interconnectedness between domestic and international markets at a higher level. Countless historical experiences have underscored the significance of embracing international openness as a driving force for sustainable and robust economic development of a country. The speech at the 2018 Boao Forum for Asia clearly conveyed China's firm stance on continuously expanding its opening-up, actively participating in global governance, and jointly promoting the establishment of a shared future for all of humanity. In particular, further opening-up of the financial market and the policy expansion of comprehensive foreign access demonstrate that China is entering into a new phase of opening-up. This not only attracts foreign investment but also stimulates the competitiveness and innovation capabilities of domestic enterprises, enabling them to effectively integrate into the global market.

Thirdly, continuous promotion of technological innovation is crucial. Technological innovation serves as the core driver for economic transformation and a vital manifestation of national competitiveness. Although China has made significant achievements in the field of science and technology in recent years, such as a rapid increase in R&D expenditure, ranking first globally in the number of patents granted, and leading deployment of 5G technology, there is still a significant gap between China and leading technological powers in terms of the depth and breadth of technological innovation. Particularly in basic scientific research and original technology development, the contribution of universities and research institutions still needs to be improved. Therefore, in the future, China must further augment investments in scientific research, refine the research environment, bolster collaboration and exchanges with international research institutions, facilitate the application and industrialization of technological innovation outcomes, while cultivating and improving the technology market. By leading with technological innovation, China can drive the economy to achieve high-quality development.

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