Evolution characteristics of total factor productivity of industrial enterprises in Fujian Province

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Abstract. The DEA-based Malmquist index method was used to measure the total factor productivity of the industrial sector of Fujian Province and the industrial enterprises under four forms of ownership from 2004 to 2016. The research conclusions are as follows: First, the total factor productivity of the industrial sector of Fujian Province improves year by year, with an average growth rate of 8.9%. Technical progress is the only driving force for the improvement of total factor productivity. The technical efficiency, pure technical efficiency and scale efficiency remain unchanged; second, from the perspective of ownership, the total factor productivity of collective enterprises grows fastest, reaching 11.3%, followed by private enterprises (10.3%), foreign-invested enterprises (7.9%), HKMT enterprises (7.5%). Technical progress is also the only driving force. Therefore, the Fujian Provincial Government should increase investment, and support industrial enterprises to enhance the capacity for technological innovation, the conversion rate of technological achievements and the efficiency of resource allocation.

1. Introduction
The explosive growth of the industrial economy is an important driving force for China's economic growth miracle. The titles such as "Made in China" and "World Factory" are an important embodiment of China's development achievements in the industrial economy. However, it is widely believed in all walks of life that China's growth in the industrial economy is unsustainable extensive growth, and will suffer from the unfavorable situation of resource and environmental constraints, and a reduced savings rate and labor "dividend". On account of this, how to realize the transformation of China's industrial economy into an intensive growth mode relying on the quality of production factors and the improvement of utilization efficiency has become a hot issue of concern and discussion in domestic academic circles. Since total factor productivity is a key indicator to measure the "total output per unit of input of the production unit in the production process", this paper takes the industrial sector of Fujian Province as the research object, divides industrial enterprises into collective enterprises, private enterprises, HKMT enterprises and foreign-invested enterprises according to the form of ownership, and calculates the total factor productivity of the industrial sector as a whole and the four subdivided objects [1-2]. On the one hand, it complements the theoretical results of the research on the total factor productivity of industrial enterprises of different forms of ownership, and on the other hand, it provides decision-making references for policy makers to design policies to improve production efficiency of industrial enterprises of different forms of ownership.
2. Research methods, variable design and data sources

2.1. DEA-Based malmquist index method

This paper selects the DEA-based Malquist index method to calculate the total factor productivity and its growth of the industrial sector of Fujian Province and industrial enterprises under four forms of ownership. The main reasons are: First, the data envelopment analysis method (DEA) is an effective method to study the production efficiency of decision-making units containing multiple inputs and multiple outputs. The weights of input and output indicators do not need to be artificially set, avoiding errors in weight setting caused by subjective factors; second, this method constructs the frontier production possibility boundary with the method of linear programming [3]. In the process of production efficiency calculation, there is no need to set a specific production function, which can avoid the error of the result due to the wrong production function, unlike the stochastic frontier analysis method, which requires an error distribution assumption; Third, the DEA-based Malquist index method can decompose the total factor productivity growth rate into the rate of technical progress, pure technical efficiency and scale efficiency, so as to better grasp the internal driving force of the growth of total factor productivity in industry.

The Malquist productivity index is the growth rate of total factor productivity. It uses the directed output method or the directed input method to define the distance function. If an input variable matrix is given, an output distance function can be taken as the minimum proportional of the input variable matrix; If the output variable matrix is given, the output variable distance function can be taken as the minimum proportional of the output variable matrix.

This paper measures the Malquist productivity index of the industrial sector of Fujian Province and its industrial enterprises under four forms of ownership based on the input variable matrix. According to the methods of Shephard (1970) and Fare (1988), the definition of distance function of the output variable is as follows:

\[ D_0(x, y) = \inf \{ \delta : (x, y / \delta) \in p(x) \} \quad (1) \]

Where \( x \) and \( y \) represent the input indicator and input matrix, \( \delta \) Represents the directed output efficiency indicator of Farrell, \( p(x) \) is defined as a possible production set. If \( y \) is a component of \( p(x) \), the value of the function will be less than or equal to 1. If \( y \) is on the outer boundary of the possible production set, the value of the function will be equal to 1; On the contrary, if \( y \) is outside \( p(x) \), the value of the function will be greater than 1.

Caves et al. (1982) first defined the output variable based Malquist productivity index (total factor productivity growth rate) relative to a single technology:

\[ M_0^t = \frac{D_0^t(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)} \quad (2) \]

\[ M_{t+1}^t = \frac{D_{t+1}^{t+1}(x_{t+1}, y_{t+1})}{D_{t+1}^{t+1}(x_t, y_t)} \quad (3) \]

Of which, \( D_0^t(x_t, y_t) \) and \( D_{t+1}^{t+1}(x_{t+1}, y_{t+1}) \) are respectively the output distance functions obtained from the production point in the same time period (i.e., \( t \) and \( t+1 \)) compared with the frontier technology. On the other hand, \( D_{t+1}^{t+1}(x_{t+1}, y_{t+1}) \) and \( D_0^t(x_t, y_t) \) are respectively the output distance functions obtained from the production point in the mixing period compared with the frontier technology.

Fare et al. (1989) gave the calculation formula of the directed output Malquist index (total factor productivity growth rate):
According to the study of Fare et al. (1993), the Malmquist index (total factor productivity growth rate) can be rewritten into an equivalent form containing two parts: rate of technical progress and technical efficiency:

\[
M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \left[ \frac{D_{0+1}^t(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)} \cdot \frac{D_0^t(x_t, y_t)}{D_{0+1}^t(x_{t+1}, y_{t+1})} \right]^{1/2}
\]

In Formula (5), the formula in the square brackets on the right is the calculation formula of the rate of technical progress, and the value is greater than 1, and the previous one is the calculation formula of the technical efficiency, respectively representing the change of the rate of technical progress and the change of technical efficiency, that is, the rate of technical progress growth rate and technical efficiency growth rate.

The technical efficiency includes two factors: pure technical efficiency and scale efficiency, so the calculation formula of the Malmquist index (total factor productivity growth rate) can also be rewritten into the following equivalent form:

\[
M_0(x_t, y_t, x_{t+1}, y_{t+1}) = \frac{S_0'(x_t, y_t) \cdot D_0^t(x_t, y_t / VRS) \cdot \left[ \frac{D_{0+1}^t(x_{t+1}, y_{t+1})}{D_0^t(x_t, y_t)} \cdot \frac{D_0^t(x_t, y_t)}{D_{0+1}^t(x_{t+1}, y_{t+1})} \right]^{1/2}}{S_0'(x_{t+1}, y_{t+1})}
\]

Of which, the three items on the right in Formula (6) are scale efficiency, technical efficiency, and rate of technical progress respectively. That is, the change of the Malmquist index (total factor productivity growth rate) is finally decomposed into the change of pure technical efficiency, the change of scale efficiency, and the change of the rate of technical progress. The values of the four indicators may be equal to 1, greater than 1 and less than 1, indicating no change, improvement and regression, respectively.

2.2. Input and output indicator design

First, input indicator design. Capital and labor inputs are conventional inputs in the measurement of total factor productivity in industry. Of which, capital input indicators such as the mean depreciation of fixed assets, the original value of fixed assets, the capital stock calculated based on the perpetual inventory method, the average annual balance of net fixed assets, and the total fixed assets are widely used; In the design of labor input indicator, the average salary of employees, the number of employees, the average number of employees and the total of wages are often used [4]. In addition, indicators such as scientific research input, intermediate input, selling cost, administrative expenses and financial expenses are also included in the input. On the basis of previous studies, we select the total fixed assets as a measurement indicator of capital input and the number of employees in the industry at the end of the year as a measurement indicator of labor input. Due to the lack of data (the selling expenses were not counted in 2003-2011), other input indicators such as administrative expenses, sales expenses, and financial expenses are not introduced.

Second, output indicator design. Gross industrial output value, gross industrial sales output value and industrial added value are widely used output indicators. Some scholars use gross industrial output value, some scholars use industrial added value, but rarely use both of them. This paper uses the gross industrial sales output value as the output indicator, the reasons are as follows: The data of industrial added value are not available after 2008; The data of gross industrial output value are not available after 2012; It is even more difficult to obtain the added value and gross output value created by industrial enterprises under four forms of ownership.

2.3. Data
In this paper, the data of input and output indicators of the industrial sector of Fujian Province and its collective industrial enterprises, private industrial enterprises, HKMT enterprises and foreign-invested industrial enterprises are all from the *Industrial Statistics* sub-database of drcnnet.com.

3. Result analysis

3.1. The evolution of the number of employees in the industrial sector

It can be seen from Figure 1 that, during 2003-2016, the number of employees in the industrial sector of Fujian Province increased from 2.2135 million to 4.2166 million, showing an increase year by year as a whole. Only in 2009 due to the 2008 global financial crisis and in 2011 due to the impact of the debt crisis in Europe, is the reduction in output of export-oriented enterprises and the resulting reduction in output of upstream enterprises ultimately lead to a decline in the number of employees in the industrial sector; Compared to 2015, the decline in 2016 may be due to the increased environmental regulations in China, the backward production capacity of the industrial sector and the adjustment of industrial structure in Fujian Province. From the perspective of different forms of ownership, their driving capacities for social employment are different: The driving capacity for social employment of private enterprises are the strongest, followed by HKMT enterprises and foreign-invested enterprises; As for collective enterprises, due to the reform or restructuring of state-owned and collective enterprises in the late 1990s, many state-owned enterprises and collective enterprises have been restructured into joint stock limited companies, limited liability companies and private enterprises. Their contribution to employment is very small and presents a declining trend year by year, from 98,300 in 2003 to 13,200 in 2016. In addition, HKMT enterprises and foreign-invested enterprises that used to be the mainstay of Fujian's industrial economy are gradually shrinking, and their employment-driven capabilities have been replaced by local private enterprises. On the one hand, it shows that the number of local enterprises grows and the scale of development expands; on the other hand, it indicates that it is of great economic and practical significance to strengthen the support and assistance for local private enterprises.

![Figure 1](image_url)

**Figure 1.** Changes in the number of employees in the industrial sector of Fujian Province.

Unit: 10,000 people.

Note: HKMT enterprises are firms owned by enterprises or individuals in Hong Kong, Macao and Taiwan.

3.2. The evolution of total fixed assets in the industrial sector

It can be seen from Figure 2 that, during 2003-2016, the total fixed assets of the industrial sector of Fujian Province show an increase year by year, increasing from RMB 217.021 billion in 2003 to RMB...
993.169 billion in 2016. From the perspective of different forms of ownership, the total fixed assets of local private enterprises surpassed that of foreign-invested enterprises and HKMT enterprises in 2012, reaching RMB 144.961 billion, RMB 134.446 billion and RMB 133.144 billion respectively, and becoming the type of enterprise with the most capital input among the four forms of ownership. Prior to this, foreign-invested enterprises occupied the first place, and began to show a trend of decline in fluctuation in 2013. This may be due to the adjustment of national income tax policy for foreign-invested enterprises, which reduces the phenomenon of capital recycling after the local capital of Fujian Province flows to overseas registered companies, that is, reducing the emergence of "fake foreign-funded enterprises"; The second is HKMT enterprises, the total fixed assets of which have been replaced by local private enterprises as early as in 2008. Finally, the fixed asset balance of collective enterprises is the smallest, reducing from RMB 4.335 billion in 2003 to RMB 986 million in 2016. The status change of industrial enterprises in the above three forms of ownership proves once again that local private enterprises have become an important driving force for investment growth of industrial enterprises in Fujian Province.

![Figure 2](image-url)

Figure 2. Net value of fixed assets of industrial enterprises in Fujian Province.

Unit: RMB 100 million yuan.

3.3. The evolution of gross sales output value of the industrial sector

It can be seen from Figure 3 that, during 2003-2016, the gross sales value of the industrial sector of Fujian Province show an increase year by year, increasing from RMB 483.453 billion in 2003 to RMB 4,330.915 billion in 2015. None of the global financial crisis in 2008, the European debt crisis in 2011 and the strong environmental protection policies after 2015 have a negative impact on the sales growth of the industrial sector. From the perspective of different forms of ownership, the gross industrial sales output value of collective enterprises and foreign-invested enterprises decline, and the sales output value of private enterprises and HKMT enterprises shows a characteristic of increasing year by year. Among them, private enterprises have been the type of enterprises with the largest sales output value in the industrial sector since 2009. In 2016, the sales output value increased to RMB 1,479.151 billion, proving once again the significance of the stable development of private enterprises for the economic growth of Fujian Province.
3.4. Measurement results of total factor productivity in the industrial sector of Fujian Province

According to calculation formulas (1)-(6), the average of the Malmquist index of the industrial sector of Fujian Province during 2004-2016 was 1.089, indicating that the average growth rate of total factor productivity of the industrial sector was 8.9%. During the sample period, the total factor productivity of the industrial sector of Fujian Province grew every year. The growth rate was the fastest in 2011, reaching 20.3%, and the slowest in 2012, which was 1.7%. The above results indicate that the growth quality of the industrial sector of Fujian Province has been continuously improved in recent years, and certain achievements have been made in the transformation and upgrading of the industrial sector and in the transformation of economic growth pattern.

From the decomposition results of Malmquist index, technical progress is the only driving force for the growth of total factor productivity in the industrial sector of Fujian Province, because the values of the technical efficiency and its decomposition factors-pure technical efficiency and scale efficiency during 2004-2016 are both 1, that is, the technical efficiency of the industrial sector of Fujian Province has not changed during the sample period. The continuous technical progress shows that the overall technological innovation capability of industrial enterprises in Fujian Province is continuously improved, which can provide solid technical support for the effective promotion of the development strategy of high-end manufacturing in Fujian Province and the transformation and upgrading of the industrial sector. However, the technical efficiency and pure technical efficiency have not been improved, indicating that the industrial sector should strengthen the test and transformation of existing technological achievements and realize in-depth utilization; The scale efficiency has not been improved, indicating that there is still room for improvement in the efficiency of resource allocation within industrial enterprises. It is necessary to enhance the capacity utilization rate and asset turnover rate of enterprises by strengthening terminal brand marketing and channel construction capabilities.

Table 1. Comprehensive Productivity of the Industrial Sector of Fujian Province and its Decomposition.

| Year | Technical efficiency | Rate of technical progress | Pure technical efficiency | Scale efficiency | Total factor productivity |
|------|----------------------|---------------------------|--------------------------|-----------------|--------------------------|
| 2004 | 1.000                | 1.136                     | 1.000                    | 1.000           | 1.136                    |
| 2005 | 1.000                | 1.107                     | 1.000                    | 1.000           | 1.107                    |
3.5. Measurement results of total factor productivity of industrial enterprises under four forms of ownership

This paper has calculated the Malmquist index of collective enterprises, private enterprises, HKMT enterprises and foreign-invested enterprises in the industrial sector, and found three main conclusions: First, the technical efficiency, pure technical efficiency and scale efficiency indexes of industrial enterprises under four forms of ownership remain 1 during the sample period, indicating that the technical efficiency, pure technical efficiency and scale efficiency remain unchanged, and the conversion efficiency of technological achievements, the in-depth mining capability and the assets operation capability of the four types of enterprises still need to be further improved; Second, technical progress is the only factor affecting the increase or decrease in total factor productivity of industrial enterprises under four forms of ownership, which is consistent with the overall findings of the industrial sector, proving once again the important practical significance of encouraging and supporting enterprises to increase investment in technological innovation; Third, unexpectedly, the average growth rate of total factor productivity of collective enterprises was the highest during the sample period, reaching 11.3%; Followed by private enterprises, foreign-invested enterprises, and HKMT enterprises, respectively 10.3%, 7.5%, 7.9%. That's to say, the quality of development of local enterprises is generally better than HKMT enterprises and foreign-invested enterprises, which are often considered to be more advanced in management and technology.

Table 2. Total Factor Productivity of Industrial Enterprises Under Four Forms of Ownership.

|        | Collective enterprises | Private enterprises | HKMT enterprises | Foreign-invested enterprise |
|--------|------------------------|---------------------|------------------|-----------------------------|
| 2004   | 1.061                  | 1.120               | 0.914            | 1.044                       |
| 2005   | 1.106                  | 1.095               | 0.927            | 1.122                       |
| 2006   | 1.195                  | 1.063               | 1.525            | 1.075                       |
| 2007   | 1.124                  | 1.140               | 1.046            | 1.154                       |
| 2008   | 1.154                  | 1.073               | 1.090            | 1.104                       |
| 2009   | 1.120                  | 1.080               | 1.028            | 0.959                       |
| 2010   | 1.066                  | 1.137               | 1.161            | 1.276                       |
| 2011   | 1.387                  | 1.294               | 1.181            | 1.106                       |
| 2012   | 0.913                  | 1.029               | 0.975            | 1.047                       |
| 2013   | 1.063                  | 1.075               | 1.086            | 1.018                       |
| 2014   | 1.113                  | 1.073               | 1.023            | 1.080                       |
| 2015   | 1.080                  | 1.079               | 1.099            | 0.998                       |
| 2016   | 1.140                  | 1.100               | 1.033            | 1.077                       |
| Average| 1.113                  | 1.103               | 1.075            | 1.079                       |

4. Conclusions and revelation

The improvement in the quality of development of the industrial sector is an important foundation for the sustainable and high-quality development of the economy of a country. This paper, taking the total
fixed assets and the number of employees as the input indicators and the gross industrial sales output value as the output indicator, measures the Malmquist index of the industrial sector of Fujian Province and industrial enterprises under four forms of ownership during 2004-2016 with DEA-based Malmquist index method, so as to identify the total factor productivity growth in the industrial sector of Fujian Province and its root causes. The main research conclusions are as follows: First, during 2004-2016, the total factor productivity of the industrial sector of Fujian Province increased year by year, with an average growth rate of 8.9%, indicating that the quality of growth of the industrial sector of Fujian Province has been improved, and certain achievements have been made in the transformation and upgrading of the industrial sector and in the transformation of economic growth pattern; Second, technical progress is the only driving force for the improvement of industrial total factor productivity. The technical efficiency, pure technical efficiency and scale efficiency remain 1, indicating that the conversion efficiency of technological achievements and the efficiency of resource allocation of the industrial sector of Fujian Province need to be improved; Third, from the perspective of ownership, the total factor productivity of collective enterprises grows fastest, reaching 11.3%, followed by private enterprises (10.3%), foreign-invested enterprises (7.9%), HKMT enterprises (7.5%). But technical progress is also the only driving force for the total factor productivity improvement of the four types of enterprises; Fourth, based on the above conclusions, the Fujian Provincial Government should increase policy support for industrial enterprises in technological innovation, support industrial enterprises to increase investment in the research and development of new technologies, new processes, new products and new materials, and support industrial enterprises to improve the conversion rate of technological achievements and the efficiency of resource allocation, increase support for industrial enterprises to introduce and absorb new technologies, new process equipment and new management systems, transform the pattern of economic development, change the extensive management pattern, and provide new driving forces for industrial transformation and upgrading.

References
[1] Caves D W, Christensen L R, Diewert W E. The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity[J]. Econometrica, 1982, 50(6):1393-1414.
[2] Fare R, Grosskopf S, Lovell C A K, et al. Derivation of Shadow Prices for Undesirable Outputs: A Distance Function Approach[J]. Review of Economics & Statistics, 1993, 75(2):374-380.
[3] Färe R. Fundamentals of Production Theory[M. Fundamentals of production theory. Springer-Verlag, 1988.
[4] Shephard R W. Theory of Cost and Production Functions[M]. Princeton University Press, 2015.