Study on Production Efficiency of Flue-cured Tobacco in China Based on DEA-Malmquist Model

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Abstract. Based on the input-output data of flue-cured tobacco production in 18 provinces of China from 2005 to 2016, the flue-cured tobacco production efficiency was calculated and analyzed. The results show that: Firstly, the total factor productivity (TFP) of flue-cured tobacco in China shows a growth trend, the main reason of the growth is the growth of the scale efficiency. The pure technical efficiency and the technical progress play a negative role to the promotion of total factor productivity. Secondly, in the provinces where total factor productivity declines, the leading factors of total factor productivity declines are different. For the provinces where total factor productivity increases, the leading factor of total factor productivity growth is the improvement of technical efficiency. Thirdly, the change of annual total factor productivity growth rate is unstable because of the uncoordinated change of technological progress and technological efficiency. We can improve the flue-cured tobacco productivity by large-scale production, improving management level, introducing advanced production technology and strengthening technological innovation.

1. Introduction
China's tobacco industry is a major contributor to national tax revenue. The annual tax revenue of the industry is as much as 10% of the total national tax revenue, which plays an important role in China's economic development. Flue-cured tobacco production is the basis of the whole cigarette industry and the value appreciation of the whole industrial chain of the tobacco industry. Its output and quality directly affect the economic interests of the tobacco industry. With the regulation of the state on the tobacco industry, the planting area and yield of flue-cured tobacco are restricted. Meanwhile, the material cost and labor cost in the production of flue-cured tobacco increase year by year, and the comparative advantage of flue-cured tobacco is gradually lost. Therefore, it has become an urgent problem to analyze the input-output efficiency of flue-cured tobacco production and explore the ways to reduce production cost and improve the production efficiency of flue-cured tobacco.

The study of flue-cured tobacco production efficiency by Chinese scholars has been quite common. In terms of research methods, stochastic frontier method (SFA) and data enveloping analysis (DEA) are mostly used, but DEA-Malmquist model is rarely used to study the production efficiency of flue-cured tobacco in China. DEA-Malmquist model does not need to determine the production function and related parameters which avoids the influence caused by the unreasonable model setting in SFA. In addition, DEA-Malmquist model not only can process panel data containing multiple time point observations, but also can measure technological progress, which makes up for the deficiency of DEA.
Therefore, DEA-Malmquist model was selected to calculate and analyze the flue-cured tobacco production efficiency in China based on the input and output panel data of 18 provinces from 2005 to 2016, and suggestions and countermeasures were put forward to promote the development of China’s flue-cured tobacco production.

2. Research methods and data description

2.1. Research methods
Data envelopment analysis (DEA) is a non-parametric efficiency evaluation method that uses linear programming method to evaluate whether the same type of decision making unit (DMU) with multiple inputs and outputs is technically effective and scale-effective. The Malmquist index method is a measure of productivity. Fare R et al. (1992) first used DEA method to calculate Malmquist index and decomposed the Malmquist index into two aspects, namely, technical efficiency change (EC) and change in production technology (TC). Fare R et al. (1994) further decomposed the technical efficiency change (EC) into pure technical efficiency change (PEC) and scale efficiency change (SEC). The decomposition formula of Malmquist index is as follows:

\[ M = PEC \times SEC \times TC \]

Among them, M represents Malmquist index. When M>1, productivity increases, when M<1, productivity decreases, and when M=1, productivity does not change.

2.2. Data sources and descriptions
The basic data were obtained from the data compilation of national agricultural product cost and income. Considering the availability and rationality of the data, the output of the main product per 667 m\(^2\) of flue-cured tobacco was selected as the output variable, and the number of workers per 667 m\(^2\) and the material cost per 667 m\(^2\) were selected as the input variable. The material cost includes seed cost, fertilizer cost, farm manure cost, pesticide cost, agricultural film cost, fuel and power cost, etc. In order to avoid the impact of price fluctuation, the price index of means of production of planting products was adopted to adjust material cost based on 2005.

3. Empirical analysis
Deap2.1 software was used to analyze the input-output data of 18 flue-cured tobacco producing areas in China from 2005 to 2016, and Malmquist index and its decomposition in different regions were obtained, as shown in table 1:

| Region            | EC    | TC    | PEC   | SEC   | TFPCH |
|-------------------|-------|-------|-------|-------|-------|
| Liaoning          | 1.031 | 0.995 | 1.017 | 1.014 | 1.026 |
| Gilin             | 1.007 | 1.001 | 1.014 | 0.994 | 1.008 |
| Heilongjiang      | 1.000 | 0.996 | 1.000 | 1.000 | 0.996 |
| Anhui             | 0.983 | 1.000 | 0.977 | 1.006 | 0.983 |
| Fujian            | 1.046 | 0.991 | 1.001 | 1.045 | 1.037 |
| Jiangxi           | 1.033 | 0.995 | 1.010 | 1.023 | 1.029 |
| Shandong          | 1.018 | 0.996 | 0.984 | 1.035 | 1.014 |
| Henan             | 1.001 | 0.996 | 0.997 | 1.004 | 0.997 |
| Hubei             | 0.986 | 0.991 | 0.981 | 1.005 | 0.977 |
| Hunan             | 1.029 | 0.989 | 0.980 | 1.050 | 1.018 |
| Guangdong         | 1.039 | 0.990 | 1.006 | 1.033 | 1.029 |
| Guangxi           | 1.015 | 0.989 | 0.991 | 1.025 | 1.004 |
| Chongqing         | 1.018 | 0.998 | 1.002 | 1.016 | 1.016 |
| Sichuan           | 0.990 | 0.991 | 0.999 | 0.991 | 0.982 |

Table 1. Malmquist index and its decomposition in different regions sections
As can be seen from table 1, the annual average Malmquist index of Heilongjiang, Anhui, Henan, Hubei, Sichuan and Shanxi from 2005 to 2016 was less than 1, that is, total factor productivity shows a downward trend. Among them, the main reason for the decline of total factor productivity in Heilongjiang is the regression of technology. Therefore, Heilongjiang should increase investment in innovation, vigorously support scientific and technological innovation and improve the efficiency of transformation of scientific and technological achievements to promote the improvement of productivity. The decline of total factor productivity in Anhui is mainly caused by the decline of pure technical efficiency, at the same time, technological progress and scale efficiency show positive growth, which shows that we should not only improve productivity through technological progress and economies of scale, but also promote the improvement of pure technical efficiency by optimizing resource allocation and improving management level. The total factor productivity of flue-cured tobacco in Henan and Hubei is in a state of technological regression and pure technological efficiency decline, and the productivity can be improved by increasing scientific and technological innovation and optimizing resource allocation. The decline of total factor productivity in Sichuan and Shanxi is caused by technological regression and reduction of pure technology and scale efficiency, which requires Sichuan and Shanxi to improve flue-cured tobacco productivity by scientific and technological innovation, optimizing resource allocation, improving management level and reducing planting scale appropriately. It can be seen that, the reasons for the reduction of total factor productivity are different in those provinces. Therefore, countermeasures to improve flue-cured tobacco productivity should be formulated according to the specific conditions of each province.

For all the provinces with the improvement of total factor productivity, except Gansu, all the other provinces show the regression of technology. The leading factor driving the growth of total factor productivity is the improvement of comprehensive technical efficiency. Therefore, these provinces should pay more attention to scientific and technological innovation, needs to enhance investment in innovation, architecture technology innovation system, form effective innovation mechanism and increase policy support and talent introduction.

In terms of the whole country, the annual average total factor productivity of flue-cured tobacco from 2005 to 2016 is 0.8%, showing a weak growth trend, which is mainly driven by the growth of scale efficiency, and both pure technical efficiency and technical progress have negative effects on total factor productivity. The fluctuation rate of annual total factor productivity of flue-cured tobacco in each province is relatively small, with the lowest growth rate of total factor productivity being -2.3% in Hubei, and the highest growth rate of total factor productivity being 3.7% in Fujian. It can be concluded that the flue-cured tobacco productivity in each province is stable, and the flue-cured tobacco production is in a relatively slow development period, which indicates that the production of flue-cured tobacco in China has been difficult to expand output depending on factor input. Therefore, it is urgent to change the development mode, reduce costs, increase efficiency and improve quality through supply-side reform and innovation-driven development.

| Year    | EC  | TC  | PEC | SEC | TFPCH |
|---------|-----|-----|-----|-----|-------|
| 2005-2006 | 1.115 | 0.968 | 1.008 | 1.107 | 1.080 |
| 2006-2007 | 0.857 | 1.169 | 0.929 | 0.922 | 1.002 |
| 2007-2008 | 1.063 | 0.872 | 1.051 | 1.012 | 0.927 |
| 2008-2009 | 1.029 | 0.932 | 1.028 | 1.002 | 0.960 |
| 2009-2010 | 0.942 | 1.169 | 0.894 | 1.054 | 1.100 |
| 2010-2011 | 1.055 | 0.951 | 1.031 | 1.024 | 1.003 |
As can be seen from table 2 and fig.1, the change curve of Malmquist index fluctuates around 1, and the change curves of the technology progress index and the comprehensive technology efficiency index are alternately above and below the Malmquist index, which shows that the change of total factor productivity growth rate is instability, and the factors that affect the change are the change of technical level and comprehensive technical efficiency. It shows that when the growth rate of technological progress is positive, the growth rate of technological efficiency is negative, and when the growth rate of technological efficiency is positive, the technological progress is negative, which may be related to the uncoordinated change of between technological progress and technological efficiency. Therefore, the improvement of flue-cured tobacco productivity should pay attention to coordinate the relationship between technology innovation and management innovation, increase scientific and technological innovation, constantly optimize the allocation of resources and improve the management level. In addition, the intermittent and hysteresis of technological innovation may also affect the unsustainable improvement of total factor productivity, therefore, it is necessary to accelerate the construction of a technological innovation system, vigorously cultivate innovative talents and form a mechanism for sustained innovation.

4. Conclusion
By using the DEA-Malmquist model, we analyzed the flue-cured tobacco total factor productivity in China based on input-output data of 18 provinces from 2005 to 2016, and the conclusions were as follows: Firstly, the total factor productivity of flue-cured tobacco in China shows a growth trend, the main reason of the growth is the growth of the scale efficiency. The pure technical efficiency and the technical progress plays a negative role to the promotion of total factor productivity. Secondly, in the provinces where total factor productivity declines, the leading factors of total factor productivity declines are different. For the provinces where total factor productivity increases, the leading factor of total factor productivity growth is the improvement of technical efficiency. Thirdly, the change of annual total factor productivity growth rate is unstable because of the uncoordinated change of technological progress and technological efficiency.

According to the conclusion of the study, several suggestions are put forward to improve the total factor productivity of flue-cured tobacco in China: (1) On the premise of maintaining the existing cultivated area of flue-cured tobacco, we should accelerate the guidance of land circulation, form large-scale production, organize farmers and strengthen the professional division of labor. (2) we
should establish a professional management team, strengthen the management level of flue-cured tobacco production and introduce a market mechanism to strengthen competition. (3) we should establish a technological innovation system for tobacco agriculture, create a technological innovation environment, form a technological innovation mechanism and accelerate the transformation of scientific and technological achievements.

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