Research on Agricultural Production Efficiency of Guizhou Province Based on DEA-Malmquist Model

Dongbing Huang*, Xinlei Wang

*Department of Management Science, Guizhou University of Finance and Economics, Guiyang, Guizhou, 550025, China

**Department of Management Science, Guizhou University of Finance and Economics, Guiyang, Guizhou, 550025, China

*Corresponding author’s e-mail: huangdongbing@mail.gufe.edu.cn

Abstract. The continuous improvement of agricultural production efficiency is an important guarantee for the development of modern agriculture. Based on the input-output data of agricultural production in 9 cities of Guizhou from 2005 to 2014, the agricultural production efficiency was analyzed by the DEA-Malmquist index method. It shows that: Firstly, the total factor productivity (TFP) of agriculture in Guizhou showed a decline trend, the growth rate of total factor productivity was -1.9%, and the main reason of the decline is the reduction of pure technical efficiency and scale efficiency. Secondly, the leading factors of total factor productivity decline are different in different regions of Guizhou. Thirdly, the main reason for the fluctuation of Malmquist index with time is technological progress, and technological progress plays an important role in improving productivity. Scale operation, the enhancement of management level, and the enhancement of scientific and technological innovation can be used to enhance agricultural productivity.

1. Introduction

Agriculture is one of the major national economic industries supporting the economic development of Guizhou. In 2016, the GDP of Guizhou reached 1177.673 billion yuan, among which agriculture contributed 194.432 billion yuan, accounting for 16.5% of the GDP of Guizhou. As Guizhou is a typical mountainous agricultural province, limited by the natural environment, there are some problems such as large-scale production difficulties and obstacles to the popularization of mechanization. According to the statistics, the total output value of agriculture in Guizhou remained basically stable after 2012, at the same time, the sown area of major crops has been increasing year by year, which indicates that the agricultural economic development cannot be well promoted only by factor input. Therefore, how to improve the efficiency of agricultural production in Guizhou and promote the continuous growth of the total agricultural output value has become an urgent problem to be solved.

The study of agricultural production efficiency by Chinese scholars has been quite common. In terms of research methods, stochastic frontier analysis method (SFA) and data envelopment analysis method (DEA) are mostly used, but DEA-Malmquist model is seldom used to study agricultural production efficiency, especially, there are few studies on agricultural production efficiency in Guizhou. 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 used to calculate and analyze the technical efficiency of agricultural production based on the input-output data of 9 cities in Guizhou from 2005 to 2014, and suggestions for agricultural development in Guizhou were put forward.

2. Research methods and data description

2.1. Research methods

We assume that \((x', y')\) and \((x'^{t+1}, y'^{t+1})\) represent the input and output variables of DMU at \(t\) period and \(t+1\) period. The reference set is set, that is, \(t\) period and \(t+1\) period are used as the reference frontier respectively, and \(D_t\) and \(D_{t+1}\) are respectively used to represent the distance function with period \(t\) and \(t+1\) as the reference frontier. Taking period \(t\) as the reference frontier, the Malmquist index \(M_t\), that is, the ratio of the distance function in period \(t+1\) to the distance function in period \(t\) was calculated, taking period \(t+1\) as the reference frontier, and \(M_{t+1}\) was obtained in the same way. The geometric mean of \(M_t\) and \(M_{t+1}\) was calculated as the Malmquist index of DMU:

\[
M(x'^{t+1}, y'^{t+1}, x', y') = \sqrt{\frac{D_t'(x'^{t+1}, y'^{t+1})}{D_t'(x', y')}} \cdot \frac{D_{t+1}'(x'^{t+1}, y'^{t+1})}{D_{t+1}'(x', y')}
\]

When \(M > 1\), productivity increases; when \(M < 1\), productivity decreases; when \(M = 1\), productivity does not change.

Technical efficiency changes (EC) are as follows:

\[
EC = \frac{D_{t+1}'(x'^{t+1}, y'^{t+1})}{D_t'(x', y')}
\]

Technological change (TC), that is, the relative forward movement of the frontier in two periods, can be expressed as:

\[
TC = \frac{D'_t(x', y')}{D_{t+1}'(x'^{t+1}, y'^{t+1})} \cdot \frac{D_{t+1}'(x'^{t+1}, y'^{t+1})}{D_t'(x', y')}
\]

Malmquist index can be decomposed into efficiency change and technical change:

\[
M(x'^{t+1}, y'^{t+1}, x', y') = \frac{D_{t+1}'(x'^{t+1}, y'^{t+1})}{D_t'(x', y')} \cdot \frac{D_t'(x', y')}{D_{t+1}'(x'^{t+1}, y'^{t+1})} = EC \times TC
\]

Under the condition of VRS, technical efficiency change can be divided into pure technical efficiency change (PEC) and scale efficiency change (SEC):

\[
EC = \frac{D_{t+1}'(x'^{t+1}, y'^{t+1})}{D_t'(x', y')} = \frac{D_{t+1}'(x'^{t+1}, y'^{t+1})}{D_t'(x', y')} \cdot \frac{D_t'(x', y')}{D_{t+1}'(x'^{t+1}, y'^{t+1})} = PEC \times SEC
\]

Among them, \(D_t(\cdot, \cdot)\) represents the distance function on the condition that variable return to scale and \(D_c(\cdot, \cdot)\) represents the distance function on the condition that constant return to scale.

Thus, Malmquist index can be decomposed into:

\[
M(x'^{t+1}, y'^{t+1}, x', y') = PEC \times SEC \times TC
\]
2.2. Data sources and descriptions
The basic data comes from Guizhou Statistical Yearbook, and the panel data of 9 cities in Guizhou from 2005 to 2014 were selected for research. The total output value of agriculture, forestry, animal husbandry and fishery was selected as the output index. In order to avoid the impact of price fluctuation, the price index was adopted to adjust the total output value of agriculture, forestry, animal husbandry and fishery based on 2005. The four indexes of employment in rural primary industry (ten thousand people), total sown area of crops (thousand hectares), total power of agricultural machinery (ten thousand) and fertilizer consumption (tons) were selected as input indexes.

3. Empirical analysis
DEAP 2.1 software was used to analyze the agricultural input-output data of 9 cities in Guizhou from 2005 to 2014, and Malmquist index and its decomposition in different regions were obtained, as shown in table 1:

| Region    | EC  | TC  | PEC | SEC | TFP |
|-----------|-----|-----|-----|-----|-----|
| Guiyang   | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 |
| Liupanshui| 0.976 | 1.016 | 1.000 | 0.976 | 0.992 |
| Zunyi     | 0.969 | 1.022 | 1.000 | 0.969 | 0.991 |
| Anshun    | 0.966 | 1.033 | 0.966 | 1.000 | 0.998 |
| Tongren   | 0.933 | 0.972 | 0.957 | 0.975 | 0.907 |
| Qianxinan | 0.944 | 1.026 | 0.938 | 1.006 | 0.969 |
| Bijie     | 1.016 | 0.981 | 1.005 | 1.011 | 0.998 |
| Qiandongnan| 0.974 | 1.018 | 0.969 | 1.005 | 0.991 |
| Qiannan   | 0.960 | 1.025 | 0.952 | 1.008 | 0.984 |
| Mean      | 0.971 | 1.010 | 0.976 | 0.994 | 0.981 |

From table 1, the average agricultural total factor productivity in Guizhou was 0.981 from 2005 to 2014, showing a declining trend, the main reason is the decline of pure technical efficiency and scale efficiency. The decrease of scale efficiency indicates that agriculture in Guizhou is in the stage of diminishing returns to scale, and the productivity cannot be improved simply by expanding the planting area, but by accelerating the promotion of large-scale production, specialized division of labor and industrialized operation. Although the technical progress is 1.01 showing the technical progress, it cannot promote the improvement of total factor productivity, which indicates that the technical progress alone cannot promote the improvement of productivity, but also depends on the improvement of technical efficiency, therefore, the development of agriculture in Guizhou should accelerate the optimization of resource allocation, strengthen management level, and at the same time, continue to speed up technical progress and improve the quality of the development of agriculture through technical innovation and transformation of scientific and technological achievements.

For each city in Guizhou, only the total factor productivity of Guiyang remained unchanged at 1.000, and the technological progress index, pure technological efficiency index and scale efficiency index were all 1. The total factor productivity index of other cities was below 1. Among them, the decrease of total factor productivity in Liupanshui and Zunyi is mainly caused by the decrease of scale efficiency, therefore, these two cities should accelerate the promotion of large-scale agricultural operation and moderately reduce the planting area. The decrease of total factor productivity in Anshun, Qianxinan, Qiantongnan and Qiannan is mainly caused by the decrease of pure technical efficiency, therefore, these cities should pay attention to improving the management level, optimizing resource allocation and exploring the internal potential. The decrease of total factor productivity in Bijie is caused by technical regression, therefore, it is necessary to accelerate the pace of technological innovation and pay attention to the transfer and transformation of innovation results in agriculture in Bijie. Tongren has the lowest total factor productivity which is 0.907, and the total factor productivity decreases by 9.3%, which is mainly caused by technological regression, pure technical efficiency...
reduction and scale efficiency reduction. Therefore, Tongren should not only accelerate agricultural scientific and technological innovation, but also optimize resource allocation and improve management level, and at the same time, accelerate the guidance of land circulation to form an agricultural development model of large-scale production. It can be seen that, the reasons for the reduction of total factor productivity in each city of Guizhou are different, and countermeasures to improve agricultural productivity should be formulated according to the specific conditions of each city.

Table 2. Malmquist index and its decomposition in Guizhou province in each year

| Year       | EC      | TC      | PEC     | SEC     | TFP     |
|------------|---------|---------|---------|---------|---------|
| 2005/2006  | 1.013   | 0.978   | 1.008   | 1.006   | 0.991   |
| 2006/2007  | 1.000   | 1.119   | 0.988   | 1.012   | 1.119   |
| 2007/2008  | 0.981   | 0.960   | 0.991   | 0.990   | 0.941   |
| 2008/2009  | 1.008   | 1.092   | 1.029   | 0.979   | 1.100   |
| 2009/2010  | 0.959   | 2.095   | 0.870   | 1.102   | 2.008   |
| 2010/2011  | 1.152   | 0.583   | 1.158   | 0.995   | 0.672   |
| 2011/2012  | 0.962   | 0.694   | 0.977   | 0.985   | 0.668   |
| 2012/2013  | 0.998   | 1.127   | 0.991   | 1.006   | 1.124   |
| 2013/2014  | 0.721   | 1.001   | 0.813   | 0.887   | 0.721   |
| Mean       | 0.971   | 1.010   | 0.976   | 0.994   | 0.981   |

As can be seen from table 2 and fig.1, the Malmquist index of each year fluctuates greatly, for example, from 2009 to 2010, Guizhou had the highest growth rate of agricultural total factor productivity, which was 100.8%, and from 2011 to 2012, growth rate of agricultural total factor productivity in Guizhou was the lowest at -33.2%, at the same time, the comprehensive technical efficiency, pure technical efficiency and scale efficiency of each year fluctuate slightly around 1 and maintain a stable state, which has little impact on total factor productivity. The change curve of technological progress is basically consistent with the change curve of total factor productivity, which explains the fluctuation of total factor productivity, thus, it can be concluded that technological progress plays an important role in improving total factor productivity of agriculture in Guizhou, and henceforth, Guizhou should accelerate the construction of the agricultural technological innovation system and the transformation mechanism of scientific and technological achievements, strengthen policy support and introduce talents.

In addition, from the change curve of technological progress in fig.1, the characteristics of unsustainable growth of technological progress can be obtained, which may be related to the intermittency, hysteresis and adaptability of technological innovation, indicating that the efficiency of technological innovation should be accelerated and the innovation mechanism should be formed so that the innovation can release lasting vitality through the continuous application of innovation achievements.
4. Conclusion
By using the DEA-Malmquist model, we analyzed the agricultural total factor productivity in Guizhou based on input-output data of 9 cities from 2005 to 2014, and the conclusions were as follows: Firstly, on average, the total factor productivity of agriculture in Guizhou shows a declining trend, with a growth rate of -1.9%, and the main reason for the decline is the reduction of pure technical efficiency and scale efficiency. Secondly, except that the total factor productivity of Guiyang remains unchanged, the total factor productivity of other regions all shows a declining trend, and the leading factors of decline are different in each region. Therefore, countermeasures to improve agricultural productivity should be formulated according to the specific conditions of each city. Thirdly, the main reason why the Malmquist index fluctuates with time is technological progress, and technological progress plays a significant role in improving productivity.

According to the research conclusions, we puts forward several suggestions to enhance the agricultural production in Guizhou: (1) On the premise of not increasing the cultivated area, agriculture in Guizhou should speed up the guidance of land circulation, introduce powerful operating subjects, and form large-scale production. Meanwhile, agriculture in Guizhou should organize farmers and strengthen the professional division of labor. (2) Agriculture in Guizhou should accelerate the establishment of professional management team, strengthen the management level, and increase the introduction and popularization of advanced production technologies. (3) Agriculture in Guizhou should accelerate the establishment of scientific and technological innovation system, form an efficient innovation mechanism, and create a favorable environment for innovation. At the same time, Guizhou should promote the in-depth integration of the Internet, big data and artificial intelligence with agriculture, and create a new model for agricultural development.

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