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Evaluation of Green Total Factor Productivity of China's Tobacco Manufacturing Industry Based on DEA-Malmquist Index Method

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Abstract: Using panel data from China's tobacco manufacturing industry from 2014 to 2018, the DEA-Malmquist method is used to measure the green total factor productivity of China's tobacco manufacturing industry on the basis of comprehensive consideration of environmental pollution and energy consumption. The study found that from 2014 to 2018, the Malmquist index of green total factor productivity of China's tobacco manufacturing industry basically showed a fluctuating upward trend; the technical level of 2014-2017 needs to be improved, and the technical level of 2017-2018 has begun to improve.

1 Introduction

With the occurrence of global warming, energy shortages, ecological destruction and other issues, the international community is paying more and more attention to the increasingly severe environmental and resource issues. As the main body of China's carbon emissions is industrial enterprises, its green production transformation can promote the development of China's low-carbon economy. This article mainly studies how China's tobacco manufacturing industry can promote the sustainable development of China's economy, society and environment in a broader field, a broader scope and a higher level, so as to meet the future requirements of the international carbon labeling system and respond to domestic green production. Transformation pressure. An important measure of the economic growth of China's green transformation of the manufacturing industry is green total factor productivity, that is, the efficiency of the development and utilization of human, financial, and material resources. The research on industrial productivity mainly includes two methods, one is the stochastic frontier analysis (SFA) proposed by Aigner et al., and the other is the data envelopment analysis (DEA) proposed by Charnes et al. Through comparison, DEA does not need to formulate a certain detailed function form in advance, nor will it affect the conclusion due to a certain wrong function form. However, neither the CCR model nor the BCC model in data envelopment analysis can compare samples at the same time point. For vertical comparisons, only horizontal comparisons can be made. At present, the research on the efficiency of traditional technological innovation is also based on these two methods. Yuan Yijun et al. conducted an empirical study on the R&D efficiency of the manufacturing industry using the stochastic frontier production function, and the results showed that the size of the enterprise and government policies are the main factors affecting the R&D efficiency of the manufacturing industry. Niu Zedong and others used the stochastic frontier analysis method of the output distance function to measure the technical efficiency and scale efficiency of technological innovation activities in 7 sub-sectors of China’s manufacturing industry from 1997 to 2010, and concluded that the technological innovation efficiency of the manufacturing industry is mainly affected by the structure of property rights. And the conclusion of the impact of firm size. Duan Jie et al. used the improved DEA evaluation model to evaluate the technological innovation efficiency of seven major industries in my country's manufacturing industry. The results showed that the efficiency of technological innovation in my country's manufacturing industries is generally not high, and the use of innovative resources is insufficient. On the basis of the above-mentioned traditional technological innovation efficiency research, a small number of scholars have conducted research on the efficiency of specific technological innovation, but most of them are limited to the regional field, and there are few studies on the industrial field. Based on the perspectives of input-output efficiency and centralization efficiency, Fan Qunlin et al. measured the environmental technology innovation efficiency of 26 provinces and cities in my country's six regions, and systematically carried out the characteristics and level of environmental technology innovation efficiency in 5 provinces and cities in the southwestern region. Ground analysis. Han Jing used the DEA method to measure and analyze the green innovation efficiency of 30 provinces, autonomous regions, and municipalities in my country. The results show that the green innovation efficiency of various regions in China shows great differences. Through the analysis of the above-mentioned literature, it is found that scholars have conducted more research on the efficiency of industrial technology

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innovation, which has laid a solid foundation for the research on the efficiency of environmental technology innovation. However, the tobacco manufacturing industry is rarely studied around the efficiency of environmental technology innovation, ignoring the impact of resource consumption and environmental pollution on the tobacco manufacturing industry's environmental technology innovation efficiency. This study uses DEAP2.1 software and uses the DEA-Malmquist index method to evaluate the green total factor productivity of China's tobacco manufacturing industry and its changes in order to provide a reference for the green production transformation of China's tobacco manufacturing industry and promote the faster development of China's low-carbon economy.

2 DEA-Malmquist index model

The Malmquist index is a distance function used to describe the production technology of multiple input and output variables. Based on the DEA-Malmquist index, the green total factor productivity of the tobacco manufacturing industry is estimated by the method of output in a specific direction, and the distance function of the output variable is

$$\mathrm{D}_0(\mathrm{x},\mathrm{y}) = \inf\{\delta: (\mathrm{x},\mathrm{y}/\delta) \in \mathrm{p}(\mathrm{x})\} \quad (1)$$

In the formula: x represents the input variable, y represents the input variable matrix, δ represents Farrel's directed output efficiency index, and p(x) represents the possible production set. If y is outside the bounds of p(x), then the function value will be greater than 1; if y is at the bounds of p(x), the function value will be equal to 1; if y is within the bounds of p(x), the function value will be less than or Equal to 1. From t to (t+1), the Malmquist index, which measures green total factor productivity, is

$$\mathrm{MI}_0(\mathrm{x}_{t+1},\mathrm{y}_{t+1},\mathrm{x}_t,\mathrm{y}_t) = \left[\frac{\mathrm{D}_0^t(\mathrm{x}_{t+1},\mathrm{y}_{t+1})}{\mathrm{D}_0^t(\mathrm{x}_t,\mathrm{y}_t)} \times \frac{\mathrm{D}_0^{t+1}(\mathrm{x}_{t+1},\mathrm{y}_{t+1})}{\mathrm{D}_0^{t+1}(\mathrm{x}_t,\mathrm{y}_t)}\right]^{\frac{1}{2}} \quad (2)$$

In the formula: $(\mathrm{x}_{t+1},\mathrm{y}_{t+1})and(x_t,y_t)$ represent the input vector and output vector at (t+1) and t respectively; D_0^t and D_0^{t+1} respectively represent the distance function at the time of t and (t+1) with the technology T^t in the t period as a reference.

Taking the technology T^t in period t as a reference, the Malmquist index in terms of output is

$$\mathrm{MI}_0^t(\mathrm{x}_{t+1},\mathrm{y}_{t+1},\mathrm{x}_t,\mathrm{y}_t) = \frac{\mathrm{D}_0^t(\mathrm{x}_{t+1},\mathrm{y}_{t+1})}{\mathrm{D}_0^t(\mathrm{x}_t,\mathrm{y}_t)} \quad (3)$$

Taking (t+1) technology T^{t+1} as a reference, the Malmquist index in terms of output is

$$\mathrm{M}I_0^{t+1}(x_{t+1},y_{t+1},x_t,y_t) = \frac{D_0^{t+1}(x_{t+1},y_{t+1})}{D_0^{t+1}(x_t,y_t)} \quad (4)$$

According to Fare, if the return to scale remains unchanged, the Malmquist index can be the product of the technical efficiency change index (EC) and the technology level index (TC).

$$\mathrm{M}I_0(x_{t+1},y_{t+1},x_t,y_t) = \mathrm{E}C_0(x_{t+1},y_{t+1},x_t,y_t)TC_0(x_{t+1},y_{t+1},x_t,y_t) \quad (5)$$

$$\mathrm{E}C_0(x_{t+1},y_{t+1},x_t,y_t) = \frac{D_0^{t+1}(x_{t+1},y_{t+1})}{D_0^t(x_t,y_t)} \quad (6)$$

$$TC_0(x_{t+1},y_{t+1},x_t,y_t) = \left[\frac{D_0^t(x_{t+1},y_{t+1})}{D_0^{t+1}(x_{t+1},y_{t+1})} \times \frac{D_0^t(x_t,y_t)}{D_0^{t+1}(x_t,y_t)}\right]^{\frac{1}{2}} \quad (7)$$

If TC>1, the production possibility limit moves outwards, indicating that efficiency is improved, on the contrary, efficiency is reduced; if EC>1, the decision-making unit tends to the frontier, the efficiency becomes higher, otherwise, the efficiency becomes lower. At the same time, the technical efficiency change index (EC) can also become the product of the pure technical efficiency change index (PEC) and the scale efficiency change index (SEC).

Various distance functions related to input and output can be calculated by the linear programming method, and finally the Malmquist production rate index is obtained. If we calculate the green total factor productivity of the i-th tobacco manufacturing industry from t to (t+1), four situations can be obtained according to the distance function of DEA.

$$\begin{cases} [D_0^t\,(x_t,y_t)]^{-1} = max_{\varphi,\lambda}\varphi \\ s.t. \quad -\varphi y_{i,t} + Y_t\lambda \geq 0 \\ x_{i,t} - X_t\lambda \geq 0 \\ \lambda \geq 0 \end{cases} \quad (8)$$

$$\begin{cases} [D_0^{t+1}(x_{t+1},y_{t+1})]^{-1} = max_{\varphi,\lambda}\varphi \\ s.t. \quad -\varphi y_{i,t+1} + Y_{t+1}\lambda \geq 0 \\ x_{i,t+1} - X_{t+1}\lambda \geq 0 \\ \lambda \geq 0 \end{cases} \quad (9)$$

$$\begin{cases} [D_0^t\,(x_{t+1},y_{t+1})]^{-1} = max_{\varphi,\lambda}\varphi \\ s.t. \quad -\varphi y_{i,t+1} + Y_t\lambda \geq 0 \\ x_{i,t+1} - X_t\lambda \geq 0 \\ \lambda \geq 0 \end{cases} \quad (10)$$

$$\begin{cases} [D_0^{t+1}(x_{t+1},y_{t+1})]^{-1} = max_{\varphi,\lambda}\varphi \\ s.t. \quad -\varphi y_{i,t} + Y_{t+1}\lambda \geq 0 \\ x_{i,t} - X_{t+1}\lambda \geq 0 \\ \lambda \geq 0 \end{cases} \quad (11)$$

3 Empirical Research

3.1. Data and index selection

Data from 2014-2018 "China Environment Statistical Yearbook", "China Statistical Yearbook" and "China Labor Statistical Yearbook."

Green total factor productivity input indicators are mainly reflected in labor, capital, energy and other aspects.

(1) Labor input. Labor input usually refers to the amount of labor actually invested in production, estimated with standard intensity labor time. Due to the imperfect market mechanism and income distribution system in China, there is a lack of necessary statistical data. So this article uses "average number of workers (ten thousand people)" to measure.

(2) Capital investment. Barro et al. believe that in theory, the service flow of physical capital can be used to measure capital input. When judging capital investment, most scholars choose liquidity or net fixed assets as the standard. Therefore, this article also uses "current assets (100 million yuan)" to estimate.

(3) Energy consumption. The total energy consumption is selected to represent energy loss.

3.2. Empirical analysis

This study use the BCC model to analyze the Malmquist index of green total factor productivity in the tobacco manufacturing industry, as shown in Table 1 and Figure 1.

Table 1 The Malmquist Index and Decomposition of Green Total Factor Productivity of China's Tobacco Manufacturing Industry from 2014 to 2018

Year	EC	TC	PEC	SEC	Malmquist index
2014-2015	1.000	0.912	1.000	1.000	0.912
2015-2016	1.000	0.861	1.000	1.000	0.861
2016-2017	1.000	0.985	1.000	1.000	0.985
2017-2018	1.000	1.078	1.000	1.000	1.078
Mean	1.000	0.955	1.000	1.000	0.955

It can be seen from Table 1 and Figure 1 that the Malmquist Index of Green Total Factor Productivity of China's tobacco manufacturing industry basically showed a fluctuating and rising trend from 2014 to 2018. From 2014-2015 to 2015-2016, there was a decline, mainly due to the decrease in green total factor productivity during 2015-2016. During this period, the technical level decreased, and it gradually increased after 2016. There has been some emphasis on investment in transformation. During the period from 2014 to 2017, the Malmquist index of green total factor productivity of the tobacco manufacturing industry was less than 1. Further analysis of the structure of green total factor productivity found that the most important reason for the decline in green total factor productivity from 2014 to 2017 was the regression of technology, reflecting the relatively small investment in green production transformation of tobacco manufacturing in China at that time. During the period 2017-2018, the Malmquist index of green total factor productivity of the tobacco manufacturing industry was greater than 1, indicating that the green total factor productivity of China's tobacco manufacturing industry has begun to show an improvement trend, and there is a trend of improvement in the technical level. In addition, from the analysis of the structure of green total factor productivity, the tobacco manufacturing industry shows the same characteristics: scale efficiency and pure technical efficiency are very stable, and the Malmquist index is mainly affected by the technical level. In general, the technical level is generally progressing. situation. From the perspective of the average time series of the tobacco manufacturing industry, the average annual green total factor productivity of 2014-2016 has declined, down by 15.2%; the average annual green total factor productivity of 2015-2018 has both increased, with an average annual increase of 14.4% and respectively 9.4%.

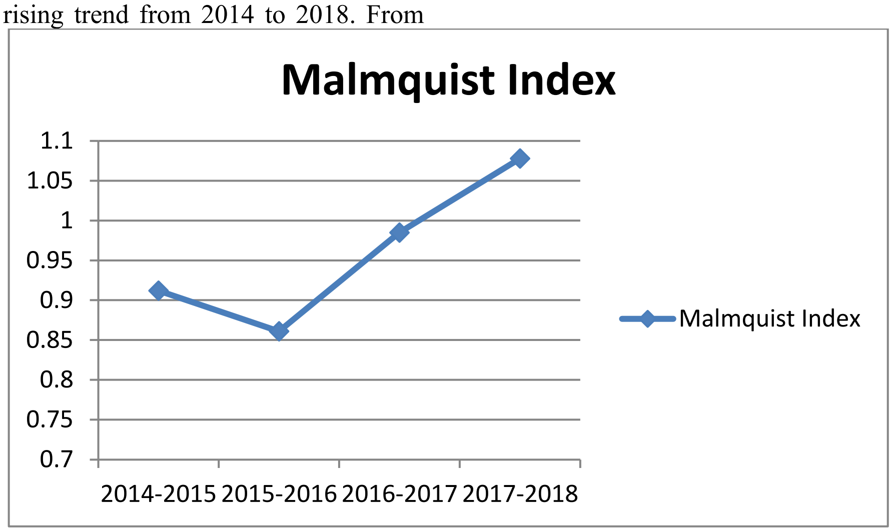

Figure 1 Malmquist index changes

4 Conclusion

Taking the panel data of China's tobacco manufacturing industry from 2014 to 2018 as a sample, the DEA-Malmquist method is used to estimate the green total factor productivity index, technology level index and technical efficiency change index of China's tobacco manufacturing industry. get conclusion:

First, from 2014 to 2018, the Malmquist Index of Green Total Factor Productivity of China's tobacco manufacturing industry basically showed a fluctuating and rising trend. From the perspective of the average time series of the tobacco manufacturing industry, the annual average green total factor productivity of 2015-2018 has increased, with an average annual increase of 14.4% and 9.4% respectively.

Second, from 2014 to 2018, the scale efficiency and pure technical efficiency of China’s tobacco manufacturing industry were stable. The Malmquist index was mainly affected by the technical level, indicating that the most important reason for the

decline in green total factor productivity was the retreat of the technical level, reflecting China’s relative Less investment in the green production transformation of the tobacco manufacturing industry. It was not until 2017-2018 that the level of technology improved, but overall, it basically showed an upward trend.

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References

1. Rolf Färe, Shawna Grosskopf, Mary Norris, Zhongyang Zhang. Productivity Growth, Technical Progress, and Efficiency Change in Industrialized Countries.J. The American Economic Review, 8,1(1994).
2. Sten Malmquist. Index numbers and indifference surfaces.J. Trabajos de Estadistica, 4,2(1953).
3. Jianzhong XU, Xiaoyu QU. Research on Environmental Technology Innovation Efficiency of Equipment Manufacturing Industry and Its Influencing Factors——Based on the Empirical Analysis of DEA-Malmquist and Tobit.J. Operations Research and Management Science, 24,1(2015).
4. Junjie LI, Yiji Jing. Research on Environmental Efficiency Measurement and Influencing Factors Based on DEA-Malmquist-Tobit Model——A Case Study of Henan Province .J. Ecological Economy , 37,2(2021)
5. Bai Lei, Li Liu. Research on Total Factor Productivity of Fruit Production in my country——Analysis Based on DEA-Malmquist Index Method.J. Productivity Research, 01(2021).
6. Yujie Jiang, Qingyuan Chen. Research on the Impact of "One Belt One Road" Initiative on the Innovation Capability of Equipment Manufacturing——Analysis Based on DEA-Malmquist Method .J. Coastal Enterprises and Science & Technology, 06(2020).