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Productivity of Forestry Industry in South China-Stochastic Frontier Analysis (2004-2017)

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Abstract:This paper is about the forest industry production efficiency in South China. This research has assessed the forestry production efficiency in the ten provinces in South China. To investigate whether the capital investment, land investment and labor affect the forestry technical efficiency and technical progress and how affect it. The stochastic frontier analysis was used to calculate the production efficiency. The results show that from 2004 to 2017 the forestry production efficiency of the ten provinces was increasing. In the future, efforts should be made to enhance the infrastructure investment, the education of forestry practitioners and the application of the advanced technology.

1. Introduction

In China, the forestry output value is an essential indicator for the economic utilization of forest resources. In 2017, the total output value of forestry industry reached 7 trillion yuan and the trade volume of forest products import and export reached 150 billion US dollars. China still maintains the status of forest products production and trade as a tremendous country [1].

The forest area as a percentage of the land area is increasing year by year. The sample area of this paper is located in the ten provinces of south China. Including Yunnan, Guizhou, Sichuan, Anhui, Fujian, Hunan, Guangdong, Guangxi, Jiangxi, Hubei. The forest land in this area is 128.36 million hectares, accounting for 41.35% of the national forest land area.

In this study, we want to measure the forestry technical efficiency involving spatiotemporal differences and further understand the influencing factors in South China. The main objective of this study is to examine the impact of technical efficiency, technical progress on forestry production growth in the case of China over the period 2004 to 2017.

2. Literature Review

Generally speaking, productive efficiency in China’s forestry industry has increased over time, and the state-owned structure has a significantly negative effect on efficiency [2]. Through the reform of forestry science and technology, we can meet the needs of national economic construction,promote the growth of forestry output and improve the level of forestry science and technology[3]. Cashore and Mc Dermott started from the goal of sustainable development of forestry to compare the forestry policies of various countries and their main comparisons were made

[4]. At present, the research of forestry circular economy model is still in its infancy stage. Although in terms of technology, we can see some preliminary discussions in China [5].

3. Theoretical Model: Stochastic Frontier Production Function (Sfa)

Based on the basic principles of the models of Battese and Coelli [6], we first use the SFA method to measure the forestry efficiency. The SFA method divides the actual output into production functions, random factors and technical inefficiency, which takes into account the influence of random factors on output. IT constructs the stochastic production frontier by using the production function and the random disturbance term, and estimates the values of each parameter by the maximum likelihood method, and then takes the conditional expectation of the technical invalid rate term as the technical efficiency value. The model is set as follows:

$$lnY_t = \beta_0 + \beta_k \ln K_{it} \beta_l \ln L_{it} + \beta_i \ln I_{it} + \beta_t T + \frac{1}{2}[\beta_{kk} (\ln K_{it})^2 + \beta_{ll} (\ln L_{it})^2 + \beta_{kk} (\ln K_{it})^2 + \beta_{ll} (\ln L_{it})^2] + \beta_{kl} \ln K_{it} \ln L_{it} + \beta_{ki} \ln K_{it} \ln I_{it} + L_{it} \ln I_{it} + \beta_{kt} \ln K_{it} T + \beta_{it} \ln L_{it} T + \beta_{it} \ln I_{it} + (V_{it} - U_{it}) \quad (1)$$

In Eq. (1), is the forestry output. K, L, I are the input factors of forestry production, which respectively refer to the capital investment, labor input and land investment. β is the parameter to be estimated. It means the i province in the t year, T is time variable. The error term is consisting of two parts. Vit is the random variables which assumed to be independent and identically distributed (iid) where N (0,). It can be positive or negative depending on the external events that are favorable or unfavorable, reflecting the degree of inefficiency of production. Efficiency error, U_{it} that represent production loss because of firm-specific technical inefficiency.

The scholars Battese and Coeli [6], assumed technical inefficiency with the equation below, In Eq. (2), TEit represents the forestry productivity of the i province in the t period, indicating the deviation between the actual output of the forestry production and the frontier of the optimal output.

$$\mu_{it} = \mu_t \exp(-\eta(t - T)) \quad (2)$$

The distribution of u_i accounted in technical inefficiency in production often assumed to be independently distributed as non- negative truncation of normal distribution, N (μ, σ2) implies the facts that is more than zero and maximum attainable level is not achievable. When there is improvement of firms' technical efficiency over time the η value is positive (η >0).Technical efficiency level of firm i at time t is the ratio of actual output to potential output and can be describe as :

$$TE_{it} = \exp(-\mu_{it})$$

The rate of technological progress is obtained from the equation 1 by taking partial derivatives of it with respect to time. The equation for technological progress is outline as below:

$$TP = \partial \ln[Y_{it}/\partial T] = \beta_t + \beta_{tt} T + \beta_{kt} \ln K_{it} + \beta_{lt} \ln L_{it} + \beta_{it} \ln I_{it} \quad (3)$$

Output elasticity and TP is evaluated as the functions of input level and can be estimated at the sample means.

3.1 Data Sources

This study uses secondary data about forestry are derived from China Forestry Statistical Yearbook, and the socioeconomic data are derived from China Statistical Yearbook and the statistical yearbook of each province. The data period is from 2004 to 2017. To eliminate the impact of inter-annual price changes, we use the comparable price index to count up the price-relevant data. All data use the year of 2004 as the reference year.

4. Model Estimation

Table 1 :Estimated Parameters in Six Different Models

Paramenters		Cobb Douglas	Translog	No technical Changes	Neutral Technical change	No technical Inefficiency	Time Invariant
γ		**0.9357**	**0.9775**	**0.8873**	**0.9177**		**0.9816**
		(98. 5145**)	(72. 7287***)	(28. 9245***)	(6. 2965***)		(76. 4769***)
μ		**0.9505**	**-1.5102**	**0.7294**	**-0.1815**		**-2.1653**
		(4. 9438***)	(-2. 3999***)	(2. 4043***)	(-0.8619)		(-1. 6615*)
η		**0.5989**	**0.058**	**0.0656**	**0.0656**		
		(14. 0887***)	(9. 2223***)	(7. 3561***)	(5. 1193***)		
loglikelihood		**57.9012**	**81.5892**	**52.7588**	**51.4549**	**56.8164**	**48.3595**

*Variables are expressed in natural logarithm. Figures in parentheses are t values. * ** *** denotes statistical significant at 10%5%and 1%respectively.

Table 1 shows the six functional form to estimate the parameters for production function by utilizing the FRONTIER 4.1 software. The main ideas of developing the six functional form are to choose which functional form the appropriate model is the best one to use in this study. There are three important parameters in the estimated model, namely as gamma (γ), mu (μ) and eta (η).γ is the variance ratio that was considered to determine which method give the superior measure either stochastic production frontier or traditional average production function. μ is to determine the inefficiency effect of the distribution by classifying it into normal distribution or truncated normal distribution. For η, the inefficiencies can be described as time-varying or time-invariant.

From the Cobb Douglas, no technical changes, neutral technical changes, no technical inefficiency and time-invariant production function, we can see that full translog model is a base for another model, and all the other models are nested in the translog model. Therefore, five production function estimated from table 1 was compared by using a likelihood ratio test to find the appropriate model. The model specification with the presence of the null and alternative hypothesis. Lambda has a chi-square distribution when the degree of freedom equal to the number of restrictions indicates the null hypothesis is true. Thus, the likelihood ratio test is summarized as table 2 below relates to the five tests of the production function.

Table 2 : Hypothesis Testing

No	***Null Hypothesis***	***Test Statistics (λ)***	***critical value***	***Decision***
1	Cobb Douglas	47.37602	24.725	Reject Ho
	$H_o=\beta_t+\beta_{kk}+\beta_{ll}+\beta_{ii}+\beta_{tt}+\beta_{kl}+\beta_{ki}+\beta_{li}+\beta_{kt}+\beta_{lt}+\beta_{it}=0$			
2	No Technical Changes	57.660748	15.086	Reject Ho
	$H_o=\beta_t+\beta_{tt}+\beta_{kt}+\beta_{lt}+\beta_{it}=0$			
3	Neutral Technical Progress	60.268578	11.345	Reject Ho
	$H_o=\beta_{kt}+\beta_{lt}+\beta_{it}=0$			
4	No Technical Inefficiency	49.54563	11.345	Reject Ho
	$H_o=\gamma+\mu+\eta=0$			
5	Time Invariant	66.4593	6.635	Reject Ho
	$H_o=\eta=0$			

The hypothesis of is rejected at 1 percent significant level indicates Cobb Douglas production function is not an adequate specification for the model. The second model which describes a change in the number of output products from the same amounts of input is also rejected at 1 percent significant level. The third model rejected the null hypothesis at 1 percent significance level. This indicates that the technical progress in China is non-neutral, where it is allowing the producers to make more output with less input. The fourth model is rejected at 1 percent significant level suggest the presence of technical efficiency. The last model is rejected at 1 percent significant level, which shows China's forest industry is time variant of the stochastic frontier production function.

Table 3 shows the parameter values estimation by using a trans log functional form. Based on the hypothesis testing on five other functional way, the trans log model is the appropriate model to estimate the parameters for production function. The four parameters, namely as gamma, mu, eta and sigma square, were used to validate the technical efficiency effect. From the trans log model, capital investment is significant at 1% level statistically. This indicates the technical efficiency effect in output residual was presence. The value of gamma is at 0.9775 and statistically significant at 1% level clarifies the output variations are due to the random error. At the same time, the presence of technical efficiency grows at a decreasing rate over the years was proven with the significance value of gamma and significant and positive value of eta at 0.058statistically significant at 1% level.

Table 3 : Translog Production Function Estimated Parameters (2004 -2017)

Paramenters	Parameters	Coefficient	Standard Error	t-ratio
Sigma Square	σ^2	0.5833	0.3258	1.7904*
Gamma	γ	0.9775	0.0134	72.7287 ***
Mu	μ	-1.5102	0.6293	-2.3999***
Eta	η	0.0580	0.0063	9.2223 ***
loglikelihood		81.5892		
*Variables are expressed in natural logarithm. Figures in parenthesis are t values. * ** ***				

5. Technical Efficiency

Table 4 : Technical Efficiency of Forest Industry (2004 - 2017)

sectors	Yunnan	Guizhou	Sichuan	Anhui	Fujian	Hunan	Guangdong	Guangxi	Jiangxi	Hubei	Average
Average	0.932	0.2754	0.5113	0.8146	0.9715	0.9406	0.762	0.6522	0.9266	0.3958	**0.7182**
Rank	3	10	8	5	1	2	6	7	4	9	

Measurement of efficiency is between the values of 0 to 1. The closer the valuer to one indicates the greater efficiency. From the table 4, we can see that the technical efficiency of the ten provinces in South China is increasing year by year. Fujian, Hunan and Yunnan provinces have high scientific and technological efficiency. Why? Firstly, their forestry resources are rich. Secondly, they have a sound forestry science and technology extension system. Thirdly, attach importance to the legislation of forestry local laws and regulations. Fourthly, they attach great importance to the development of forestry science and technology work and have made remarkable achievements. Fifthly, their forestry education system is also very sound.

We still can find the technical efficiency of Sichuan, Hubei and Guizhou provinces are very low even if they are creasing year by year. In comparison with the other seven provinces, Guizhou is mainly a mountainous area and Sichuan is located in a basin. This geomorphology has brought some limitations to forestry management and development. To increase the output of forestry, the government adopts the strategy of expanding forest land and neglects the input and development of forestry science and technology.

Technical efficiency estimates across the year show it always have an improvement throughout the year for the average technical efficiency between the value of 0.2754 and 0.9715. This implies that efficiency leads to higher productivity in each province. The wide variation in the technical efficiencies highlights the significance of each sector characteristics in terms of developed technology and management skills that able to bring higher levels of production efficiency.

6. Policy Implication

To build a complete forestry ecosystem and a well-developed forestry industry system and to implement the forestry development strategy based on ecological construction. The government must insist on technological innovation as a key measure to greatly improve forestry productivity and promote forestry development. Besides that, in order to promote the development of forestry science and technology innovation in China, the government should carry on the research to the forestry science and technology innovation, combine the forestry technology innovation's present situation for formulating the corresponding policy.

Establish a forestry science and technology extension system, realize resource sharing to solve the problem of decentralization of science and technology resources. Maintain the stability of forestry support policy and strengthen the investment of science and technology in the forestry industry. Improve the quality of afforestation and strengthen forest management and conservation management. Strengthen the cultivation of forestry talents and technology innovation and provide a certain fund subsidy for forestry science and technology innovation activities, to attract more scientific and technological talents to participate in forestry production. In order to realize the coordinated development of forestry ecology and industry, it is necessary to construct a broad supporting system.

7. Limitation and Further Research

In this paper, we replaced capital with capital investment and used urban forestry employees as the labor force, it may not be accurate. The data only chose the 14 years data from 2005 to 2017, the period is a little short. In the future study, we need to add more independent variables and can take advantage by using DEA and SFA together to analyze the production efficiency and classified it into small, medium and large enterprise for a more accurate representation of the forestry industries.

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