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Identifying factors influencing the forestry production efficiency in Northwest China

Lichun Xiong[a], Fengting Wang[b], Baodong Cheng[a,*], Chang Yu[a,*]

[a] School of Economics and Management, Beijing Forestry University, Beijing 100083, China
[b] College of Economics and Management, China Agricultural University, Beijing 100083, China

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ABSTRACT

Forestry industry has realized a rapid development in China due to the domestic and international demand for forestry products. Considering the conservation of forest ecology, China has strived to improve the forestry production efficiency. Currently, the northwestern regions have been trying to recover the ecology and make economic growth through forestry development. This research has assessed the forestry production efficiency in the six provinces in Northwest China. The stochastic frontier analysis was used to calculate the production efficiency. To conduct a spatiotemporal analysis, we measured the regional differences in forestry productivity and used global spatial autocorrelation to measure the spatial correlation degree. The regression model uncovered how the six factors influenced the forestry production efficiency in Northwest China. Our results show that from 2005 to 2015 the forestry production efficiency of the six provinces was declining. The spatial differences of the forestry production efficiency among the six provinces were gradually decreasing. Regarding the influencing factors, we found that the per capita GDP, forest coverage rate, the educational level of forestry employees and the number of township forestry technology stations had positive correlation with the production efficiency. The collective forest tenure reform had a negative effect, which hindered the efficiency at the regional level in Northwest China. 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

Forest is an important renewable resource in production and daily life. With the rapid development of China's national economy, forestry industry has also developed rapidly. By the end of 2015, the import and export trade of China's forest products had amounted to 140 billion US dollars, becoming the world's largest import and export country in forestry products trade. Meanwhile, China's domestic demand for wood and forest products has also continued to increase, which makes a relatively big pressure on supply and demand of forestry production. In order to promote and attach the importance to the sustainable development and forest management, policy makers have begun to pay more attention to enhance the forestry production efficiency (Tian and Yao, 2013). For example, China's 13th Five-Year Plan for Forestry Development was formally introduced in 2016, clearly striving to promote forest economy, forest health and meanwhile optimize the wood processing industry and other forestry secondary industry in order to essentially enhance forestry production efficiency. However, the forestry production efficiency is affected by multiple factors, such as social economy development, natural environment and, resource endowment (Viitala and Hanninen, 1998). Different regions also have different features to improve forestry production. Currently, China is facing severe ecological degradation. This problem is even more obvious in the northwestern regions. In history, the socioeconomic development of this area was relatively backward and the natural ecology was fragile due to the excessive deforestation and desertification. While, into the 21st century, with the preferential policies and capital investment (such as "The West Development Strategy"), the northwestern regions have been trying to recover the ecology and make economic growth through forestry development. What is more, the forestry industry has shown its effects in alleviating poverty and enhance local people's livelihood. Indeed, according to China Forestry Development Report from 2000 to 2015, the average annual growth rate of forestry output in Northwest China was 20%. The northwest region has been one of the areas that has the fastest economic forest[1] development. More specifically, many kinds of fruits,[2] nuts, spices, woody herbs, forest food (e.g., mushroom) in Northwest all take quite a large share in China's forestry economy. As China Forestry Statistics Yearbook (2015) shows that the industrial

* Corresponding authors at: No.35 Qinghua East Road, Haidian District, Beijing, China.
E-mail addresses: lichunxiong@bjfu.edu.cn (L. Xiong), wangft2016@cau.edu.cn (F. Wang), baodongcheng@126.com (B. Cheng), changyu@bjfu.edu.cn, chang.yu.v@gmail.com (C. Yu).

[1] Economic forest means the purpose of the forest is to specifically obtain economic benefits.
[2] In China the economic output of fruits is belonging to forestry economy.

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output of the economic forest industry in Northwest accounted for more than 20% of the whole national share. According to the 13th Five-Year Plan for Forestry Development, at present there are 49.46 million hectares of potential forest lands for afforestation in China. About 67% of the 39.58 million hectares of suitable land for forest is distributed in the arid or semiarid areas in Northwest China and North China. Thus the Northwest is an important potential region for China's forestry development (Liu, 2016). Therefore, the study about the forestry production efficiency and forestry management has great significance to improve the ecology and social economy in this region.

This research aims to measure the forestry production efficiency involving spatiotemporal differences and further understand the influencing factors in Northwest China. The outline of this research is as follows. In Section 2, the theory of production efficiency and methods will be reviewed. In Section 3, the forestry production efficiency in Northwest China will be measured by the data from 2000 to 2015, and the time and spatial characteristics will be analyzed. Based on the results of production efficiency, in Section 4 we will analyze the influencing factors of forestry production efficiency in Northwest China. Results and discussion will be presented in Sections 5 and 6. In the end, we will draw the conclusions and provide policy recommendations for the forestry development in this region.

2. Literature review and data collection

2.1. Stochastic frontier analysis and data envelopment analysis

Productivity refers to the ratio between the actual output and the maximum output at a fixed input, which reflects the attainable extent of the maximum output, the intended target and the best operational service (Bergen and Bates, 1984). At present, the research about production efficiency has become a key topic in academia. Since Aigner et al. (1977) and Meeusen & Broeck (1977) independently put forward the stochastic frontier production function, this method has been widely used to measure different kinds of production efficiency. Theoretically, Aigner and Chu (1968) decomposed the producer's efficiency into two parts: technical frontier and technical efficiency. The technical frontier depicts the boundaries of all producers' input-output functions; the technical efficiency describes the gap between the individual producers' actual technology and technical frontiers. Battese and Corra (1977) carried out a more detailed derivation, and developed the input-output function into the models that are suitable for panel data calculation. Its form can be linear, logarithmic linear, logarithm beyond and so on. In addition, economic theory argues that efficiency requires a joint function of resource allocation, capital and technical efficiency. Allocation efficiency (AE) reflects the use of factor prices and production techniques in optimal ratios; efficiency of scale economies (EE) is defined as the output levels of producing a predetermined quantity with the lowest cost at a given technical level; technical efficiency (TE) is the basis for measuring the maximum output rate under given inputs (Chavas and Cox, 1999). After that, according to the thought of Kumbhakar and Lovell (2000), the productivity is newly decomposed into four parts: technological progress (TP) refers to the accumulation and improvement of various forms of knowledge covered by technology, technical efficiency (TE), scale economies (SE) and allocation efficiency (AE), among which the scale economies (SE) refers to the increased economic efficiency caused by the expansion of production scale.

In terms of research methods, stochastic frontier analysis (SFA) and data envelopment analysis (DEA) are two methods widely used in the calculation of production efficiency (Baten et al., 2010; Chen, 2010; Fernando and Hor, 2017; Ha et al., 2008; Ibourk et al., 2004; Ma et al., 2011; Mcdonald, 2009; Zeng et al., 2017; Zhang et al., 2017). For example, Reinhard et al. (1999) and Karagiannis et al. (2003) used the production function equation of transcendental logarithmic stochastic frontier to respectively calculate the environmental efficiency of Dutch Cow Farm and the irrigation watering efficiency of Greek Anti – season Vegetable. Rahman and Rahman (2009) used the stochastic frontier model to analyze the rice production efficiency and influencing factors. The results showed that the land, irrigation and fertilizer were the main factors affecting rice production efficiency. Baten et al. (2010) used the stochastic frontier model to analyze the productivity of tea production in Bangladesh and argued that the inefficiency of tea production in Bangladesh was due to the low technical efficiency. With the similar research conclusions, Rahman et al. (2012) estimated the farm productivity based on farm scale, and found out that the productivity of large farms were higher than small farms, which was mainly due to the differences in technical efficiency. In addition, Abdulai (2016) estimated the maize production efficiency in Zambia through an improved stochastic frontier model. Apart from SFA, DEA, as a nonparametric method, is also a popular method to calculate production efficiency. In the field of environment, several scholars have discussed the production efficiency of China's regions with different DEA models under the consideration of environmental factors (Hu et al., 2008). Sequential DEA has been employed to further study the total factor productivity of China's regional total factor productivity (Wang et al., 2010). In the field of energy, Ederer (2015) used the DEA model to analyze power efficiency of Australian offshore wind. Moon and Min (2017) used the DEA model to measure energy consumption efficiency in Korea. Besides, some scholars also employed the Malmquist and Malmquist-Luenberger indices to measure the input-output efficiency, such as the eco-efficiency of China's pulp and paper industry (Yu et al., 2016).

In the study of forestry productivity, Labell and Stuart (1998) used DEA to analyze the technical efficiency level and efficiency redundancy of 23 lumberjacks. Viitala and Hanninen (1998) used DEA model to measure the allocation efficiency of production factors of 19 public welfare forests in Finland. It was found that the input-output efficiency was very different, and the input cost could be reduced by at least 20%. Siry and Newman (2001) evaluated Poland's timber production and forest management efficiency for nearly 40 years through a random frontier production function. According to the analysis of Hausenbuiller (1985), the efficiency of forestry production depended on the natural factors such as light, heat, water, soil nutrition and so on. Lee (2005) used the three-stage DEA model to analyze the allocation efficiency of production factors of 89 forest and paper companies in the world in 2001. They found out that the natural environment factors and statistical noise did have an impact on the efficiency value. The previous research also makes empirical analysis about the affecting factors of forestry production efficiency. Plentiful studies have shown that the economic development level, natural environment, resource endowment, talent and technology and natural disasters are the important factors that affect the efficiency of forestry production (Siry and Newman, 2001; Lee, 2005; Jun, 2008; Tian and Yao, 2013).

Although SFA is more complicated than the exponential method and DEA, SFA is a parametric method which is more beneficial to explain the reasons of technical efficiency loss (Musaba and Bwacha, 2014). Therefore, this research will use stochastic frontier production function to measure the forestry production efficiency of the six provinces in Northwest China. The spatiotemporal difference of forestry production efficiency of the six provinces are to be identified. Furthermore, the influencing factors will be analyzed in order to provide concrete strategies to coordinate forestry development in different provinces and formulate more scientific forestry policies.

2.2. Materials and data collection

The sample areas are located in the six provinces in Northwest China, including Inner Mongolia, Shanxi, Shaanxi, Ningxia, Gansu and Xinjiang. The location map is shown in Fig. 1. The total area of these regions is 373 million square kilometers, accounting for 39% of the total land area of the country. As of 2015, its total population had been 15595.32 million. Its forest land area is 87.1537 million hectares, which accounts for 24% of the national forest land area.