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Research Article

Research on Temporal-spatial Evolution of Regional Disparity of Forestry Total Factor Productivity in China

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Abstract: In this study, the methods of the Malmquist index analysis, global spatial autocorrelation analysis and local spatial autocorrelation are used to calculate and analyze the temporal and spatial evolution of the Forestry Total Factor Productivity based on the data from 30 provinces in China from 1997 to 2012 by using the software DEAP2.1, DeoDa, ArcGIS. The results show the following: The Forestry Total Factor Productivity presented obvious fluctuations in temporal patterns but presented stable characteristics in spatial patterns; The Forestry Total Factor Productivity showed the characteristics of discrete distribution from 1997 to 2003 and showed the characteristics of concentrated distribution from 2003 to 2012; The Forestry Total Factor Productivity in China presented obvious binary space structure; The high value agglomeration area gradually had become concentrated in the Shandong, Jiangsu and Zhejiang provinces and low concentration areas were mainly distributed in Gansu, Qinghai, Szechwan and other surrounding provinces. The main reasons for spatial distribution of Forestry Total Factor Productivity in China were the differences of macro-policy on forestry, lacking and changing of investments in forestry science and technology, the difference of forestry resource distribution and unbalanced regional economic development level.

Keywords: Forestry total factor productivity, regional disparity, temporal-spatial evolution

INTRODUCTION

In recent years, the development of forestry in China has grown quickly with the increase of forestry gross output from RMB 191.82 billion to RMB 3.95 trillion, accounting for 2.4 and 7.6% in the proportion of Gross Domestic Product (GDP) from 1997 to 2012. At the same time, with the increase of output, the forestry investment also has grown quickly, at a rate of 30.3% per year during the 16-year period. Specifically, there was only RMB 7.42 billion of forestry investment in 1997, but it reached RMB 334.21 billion in 2012. However, the forestry resources are characteristic of scarcity, which means that the forestry development could not just rely on the infinite input all the time, therefore, improving forestry efficiency has become an important measure to develop the forestry, especially for these regions where there are poor forestry resources but a large population in China. Therefore, measuring and analyzing the forestry productivity and its changing trend are of great significance for the sustainable development of forestry in China.

The forestry production efficiency has been a subject of concerns in a number of countries, notably the countries with plentiful forestry resources. In some academic literatures, the issue of forestry production efficiency was mainly based on the assumption of a constant technological level, namely concentrating on forestry production technical efficiency. From the research point of view, the foreign research mainly focused on the production technical efficiency of forestry production enterprises (Macpherson *et al*., 2009; Helvoigt and Adams, 2009; Kehinde and Omonona, 2010), forestry organizations (Sporcic *et al*., 2009), timber production and processing industry (Vahid and Sowlati, 2007; Luis *et al*., 2006; Hemmasi *et al*., 2011), while domestic research was a little different and mainly concentrated on the overall or regional forestry (Tian and Yao, 2013; Tian and Xu, 2012; Mi *et al*., 2013; Zang *et al*., 2014), forestry farmers (Xue *et al*., 2013; Zang *et al*., 2011) and forestry enterprises (He and Weng, 2012; Zhong and Cao, 2011). The production technical efficiency, however, can not be used to measure the overall level

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of forestry production efficiency because the technological change is also an important factor that could influence forestry production efficiency (Guo *et al*., 2013). The Forestry Total Factor Productivity, an index used for measuring total output per input in the process of forestry production, could fully reflect the forestry production efficiency in the condition of technology changes (Yang and Yang, 2013). Therefore, some scholars to paid attention to the field of Forestry Total Factor Productivity and many works were subsequently presented, focusing on the calculation of Forestry Total Factor Productivity of particular region (Kao, 2010; Yang, 2010), forestry farmers (Wu *et al*., 2013; Su *et al*., 2012), forestry enterprises (Zhang, 2012) and state-owned forestry regions (Chen *et al*., 2012). Generally, the current research on forestry efficiency, which is mainly measuring the Forestry Total Factor Productivity by using traditional time series data and panel data, showed a trend of diversification, but it still did not pay attention to the spatial correlation of forestry productivity in China. Therefore, in order to explore the spatial disparities and correlation of Forestry Total Factor Productivity and analyze its growth dynamic mechanism from the perspective of economic geography, this study analyzes the spatial distribution characteristics and spatial evolutionary trend by using the method of spatial econometric analysis on the basis of measuring the Forestry Total Factor Productivity.

DATA SOURCES

According to the current administrative divisions in China, there are 34 administrative regions, including 22 provinces, 4 municipalities, 5 autonomous regions, Hong Kong, Macao and Taiwan. This study selected 30 administrative regions as the research object except for Hong Kong, Macao, Taiwan and Tibet in accordance with the availability of research data. Furthermore, all the data came from *China Forestry Statistical Yearbook* and *China Statistical Yearbook* from 1997 to 2012. In addition, the input and output data that cover 1998 to 2012 were adjusted into the actual data based on 1997 according to the *Index of Investment in Fixed Assets* and *Index of Regional Gross Domestic Product*. The input variables and output variables will be used in order to calculate the Forestry Total Factor Productivity. Generally, the forestry input mainly includes the capital, labor and land. This study chose the *Forestry Employment* and *Forestry Fixed Asset Investment* as input variables because the statistics of China's forestry land area are released every 5 years and chose two variables, the *Forestry Gross Output* and the *Afforestation Area*, as the output index.

METHODS

Malmquist: Generally, two methods, the parameter method and nonparametric method, are usually used to calculate the total factor productivity. Parameter method is a statistical method in which the econometric model must be built to determine the production frontier. In the process of research, the effect of input variables on output variables can be determined by estimating the production function. Then, this part, which the input variables can not explain, is defined as the total factor productivity. At present, the most commonly used one is the Stochastic Frontier Analysis (SFA) method. Comparatively, the nonparametric method is a kind of mathematical programming method, which could effectively avoid the calculation error of subjective judgment because it need not set the specific type of production function. When measuring the total factor productivity, the most representative method is the Malmquist index method that is based on the method of Data Envelopment Analysis (DEA). Therefore, by taking advantage of this benefit, this study, which regarded every province as a decision making unit, uses the Malmquist index method to measure the Forestry Total Factor Productivity in different provinces in China. In the process of calculation, the calculation method that Fare built is used and the specific formula is as follows:

$$M_0(x_{t+1}, y_{t+1}, x_t, y_t) = [\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \cdot \frac{d_0^{t+1}(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_t, y_t)}]^{\frac{1}{2}} = \frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)} \cdot [\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^{t+1}(x_{t+1}, y_{t+1})} \cdot \frac{d_0^t(x_t, y_t)}{d_0^{t+1}(x_t, y_t)}]^{\frac{1}{2}}$$

where,

M = The Forestry Total Factor Productivity index

(x_{t+1}, y_{t+1}) = The forestry input and output vector of $t+1$ period

(x_t, y_t) = The forestry input and output vector of t period

d = The distance function

$\frac{d_0^t(x_{t+1}, y_{t+1})}{d_0^t(x_t, y_t)}$ = The Forestry Production Technical Efficiency Change index

$$[\frac{d_0^t(x_{t+1},y_{t+1})}{d_0^{t+1}(x_{t+1},y_{t+1})}\cdot\frac{d_0^t(x_t,y_t)}{d_0^{t+1}(x_t,y_t)}]^{\frac{1}{2}}$$ = The Forestry Production Technology Change index

On the condition of *Variable Returns to Scale*, technical efficiency could be decomposed into pure technical efficiency and scale efficiency further. Therefore, the above formula can also be written as:

$$M_0(x_{t+1},y_{t+1},x_t,y_t)=\frac{d_0^t(x_{t+1},y_{t+1}/VRS)}{d_0^t(x_t,y_t/VRS)}\cdot[\frac{d_0^t(x_{t+1},y_{t+1})/CRS}{d_0^{t+1}(x_{t+1},y_{t+1})/VRS}\cdot\frac{d_0^t(x_t,y_t)/VRS}{d_0^{t+1}(x_t,y_t)/CRS}][\frac{d_0^t(x_{t+1},y_{t+1})}{d_0^{t+1}(x_{t+1},y_{t+1})}\cdot\frac{d_0^t(x_t,y_t)}{d_0^{t+1}(x_t,y_t)}]^{\frac{1}{2}}$$

where,
VRS = Variable returns to scale
CRS = Constant returns to scale
$\frac{d_0^t(x_{t+1},y_{t+1}/VRS)}{d_0^t(x_t,y_t/VRS)}$ = Pure forestry technical efficiency

$$[\frac{d_0^t(x_{t+1},y_{t+1})/CRS}{d_0^{t+1}(x_{t+1},y_{t+1})/VRS}\cdot\frac{d_0^t(x_t,y_t)/VRS}{d_0^{t+1}(x_t,y_t)/CRS}]$$

is forestry scale efficiency. When the Forestry Total Factor Productivity, pure technical efficiency, scale efficiency and technological change are greater than 1, equal to 1 or less than 1, respectively, this means that the efficiency are enhanced, constant or falling.

Global spatial autocorrelation: The global spatial autocorrelation is mainly used to analyze the spatial characteristics of Forestry Total Factor Productivity from the perspective of overall regions in China. Generally, Moran's I index is used to measure the autocorrelation. The specific calculation formula is as follows:

$$Global\ Moran's\ I=\frac{\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}(Y_i-\bar{Y})(Y_j-\bar{Y})}{S^2\sum_{i=1}^{n}\sum_{j=1}^{n}\omega_{ij}}$$

where, the *Global Moran's I* is the global spatial autocorrelation index of Forestry Total Factor Productivity; *n* is 30 research regions; *i* and *j* are the i^{th} and j^{th} province; Y_i and Y_j are the Forestry Total Factor Productivity of the i^{th} and j^{th} province; $\bar{Y}$ is the average Forestry Total Factor Productivity of 30 provinces given by $\bar{Y}=\frac{1}{n}\sum_{i=1}^{n}Y_i$; S^2 is the variance of Forestry Total Factor Productivity given by $S^2=\frac{1}{n}\sum_{i=1}^{n}(Y_i-\bar{Y})$; ω_{ij} is spatial weight matrix. Specifically, the latitudes and longitudes of the capitals of 30 provinces in China are used as the spatial distance weighting matrix. In general, *Global Moran's I* value is in the range of [1, 1]. If the value is close to 1, it means the convergence tends to be more significant in 30 provinces; in contrast, if the value is close to -1, it means the decentralization tends to be more significant; if *Global Moran's I* is equal to 0, it means provinces are independent of each other. Furthermore, if *Global Moran's I* is greater than 0, it means positive correlation; if less than zero, negative correlation. Generally, *G-Moran's I* is tested by the *z* test.

Local spatial autocorrelation: The local spatial autocorrelation is mainly used to analyze the spatial correlation degree and disparity degree of Forestry Total Factor Productivity of each province and provinces around it. The *Local Moran's I* is regarded as the indicator to study the correlation of spatial correlation in this study and the formula is as follows:

$$Local\ Moran's\ I=\frac{Y_i-\bar{Y}}{S^2}\sum_{j=1,j\neq i}^{n}\omega_{ij}(Y_j-\bar{Y})$$

where, the *Local Moran's I* is the local spatial autocorrelation index of the Forestry Total Factor Productivity; the meanings of the other letters in the *Local Moran's I* index calculation formula are the same as the Global *Moran's I* formula and the *z* test method is also used for statistical tests. By taking advantage of the local spatial autocorrelation analysis, the Moran scatter plot on Forestry Total Factor Productivity can be gotten. This scatter plot mainly includes four quadrants: the first quadrant (High-High, HH), which is also called the Diffusion Effect Zone, shows the provinces of high Forestry Total Factor Productivity converge together; the second quadrant (Low-High, LH), which is also called the Transition Zone, shows the provinces of low Forestry Total Factor Productivity are surrounded by provinces of high Forestry Total Factor Productivity; the third quadrant (Low-Low, LL), which is also called the Low-speed Growth Zone, shows the provinces of low Forestry Total Factor Productivity converge together; the forth quadrant (High-Low, HL), which is also called the Polarization Effect Zone, shows the provinces of high Forestry Total Factor Productivity are surrounded by provinces of low total factor productivity. The Diffusion Effect Zone and the Low-speed Growth Zone, which present the positive spatial autocorrelation, are regarded as the Spatial Convergence and the Transition Zone and the Polarization Effect Zone, which present the negative spatial autocorrelation, are regarded as the Spatial Decentralization.

EMPIRICAL ANALYSIS

Temporal analysis on forestry total factor productivity: Firstly, this study calculated the annual Forestry Total Factor Productivity and its components from 1997 to 2012 in order to conduct an overall analysis of 30 regions in China (Fig. 1). From the point of variation, the Forestry Total Factor Productivity in China showed obvious fluctuation from 1997 to 2012. It showed a trend of growth in 2001-2003, 2004-2007, 2009-2010 and 2011-2012, comparatively showed a trend of decline in 1997-2001, 2003-2004, 2007-2009 and 2010-2009. The highest point of the Forestry Total Factor Productivity appeared in 2006-2007, when it increased by 21% and the lowest point appeared in 2003-2004, when it decreased by 32.6%. From the view of three elements that influence the variation of Forestry Total Factor Productivity, the Technology Change, which are consistent with the trend of the Forestry Total Factor Productivity, presented a situation of strong fluctuation that it presented a trend of growth in 1997-1999, 2000-2003, 2004-2008 and 2011-2012 and presented a trend of decline in 1999-2000, 2000-2004 and 2008-2011; In terms of the Forestry Pure Technical Efficiency, the trend of variation kept stable from 1997 to 2012, in which it always fluctuates up and down around the value 1; The Forestry Scale Efficiency kept stable as well in addition to the years from 2002 to 2005 and presented a consistent trend with the variation of Forestry Pure Technical Efficiency. Thus, we can know that the variation of China's Forestry Total Factor Productivity is strongly influenced by the Forestry Technology Change and the Forestry Pure Technical Efficiency and Forestry Scale Efficiency have little effect on it.

Global temporal-special distribution of forestry total factor productivity: In this study, the *Global Moran's I* of Forestry Total Factor Productivity of 30 regions in China from 1997 to 2012 were calculated by taking advantage of the formula and their significance was judged by the space arrangement of 999 times (Table 1). The results show that the z values were less than the critical value of 0.05 confidence levels from 1997 to 2012 except for the years 2000-2001, 2001-2004 and 2008-2009, namely the values of the *Global Moran's I* are not very significant. At the same time, the fact that the values of the *Global Moran's I* are close to 0 presents that Forestry Total Factor Productivity in China shows a phenomenon of random distribution. By

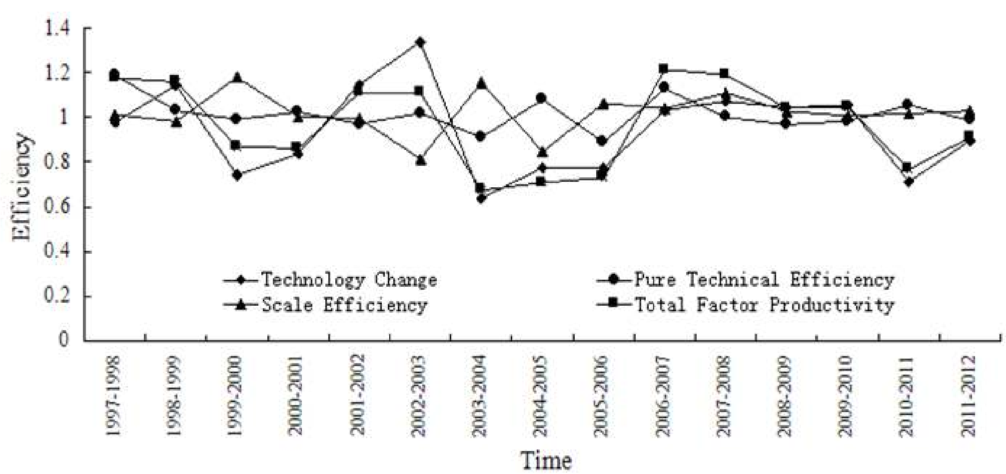


Fig. 1: The temporal changes on average of forestry total factor productivity

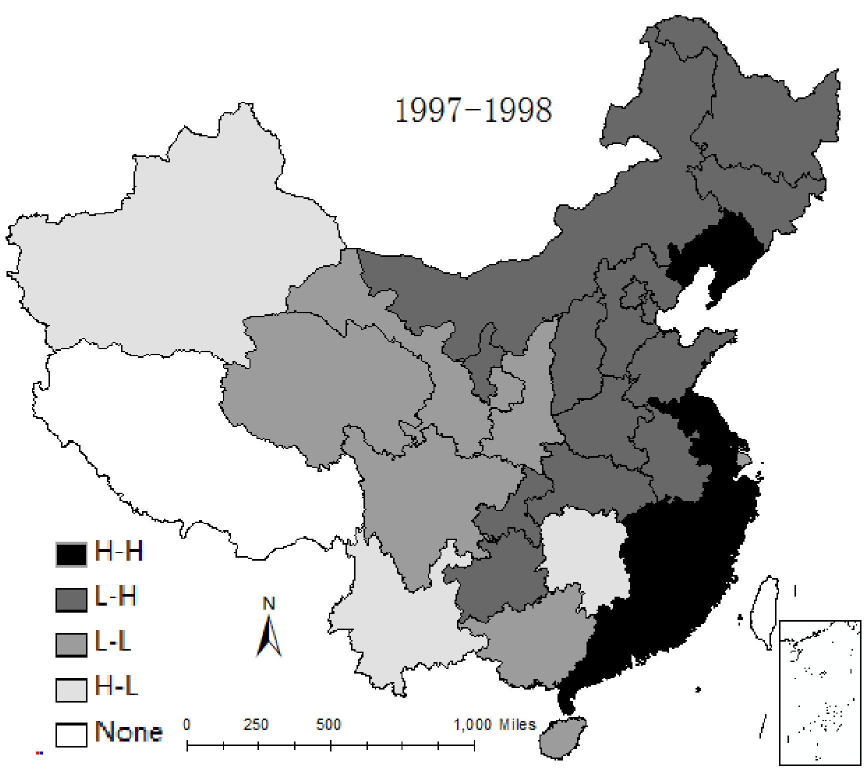
Table 1: The global spatial autocorrelation index of forestry total factor productivity in China from 1997 to 2012

Time	Global Moran's I	*z*-value
1997-1998	-0.012	0.588
1998-1999	-0.047	-0.325
1999-2000	-0.108	-1.282
2000-2001	0.095	2.871
2001-2002	-0.016	0.309
2002-2003	-0.067	-0.588
2003-2004	0.119	2.773
2004-2005	-0.053	-0.316
2005-2006	0.032	1.112
2006-2007	0.036	1.864
2007-2008	-0.069	-0.695
2008-2009	0.108	2.914
2009-2010	-0.019	0.359
2010-2011	0.054	1.539
2011-2012	0.027	1.181

observing the values of *Global Moran's I*, the total factor productivity could be divided into two periods. In the first stage, from 1997 to 2003, the Forestry Total Factor Productivity showed positive spatial autocorrelation, namely the discrete distribution, while in the second stage, from 2003 to 2012, it presented a positive spatial autocorrelation, namely the convergence distribution. However, the global spatial autocorrelation analysis just revealed the global spatial characteristics of total factor productivity and can not fully show the spatial relationship of each province and its neighbors. Therefore, this study continues to analyze the regional spatial relationship by using the local spatial autocorrelation analysis.

Local temporal-special distribution of forestry total factor productivity: Because of the strong externality, the forestry development is influenced by the policy to a large extent. China began to carry out the Natural Forest Protection Program and Sloping Land Conversion to Forest or Grass Coverage Program in 2000 and 2002 respectively and carry out the Collective Forestry Tenure Reform in 2008. Many forestry polices, which were issued along with the implementation of these projects, are bound to have an important effect on the spatial distribution of the Forestry Total Factor Productivity. At the same time, owing to the strong lag characteristics of forestry production, this study selected the year 2003-2004, when the Natural Forest Protection Program and the Sloping Land Conversion to Forest or Grass Coverage Program were implemented comprehensively, as the research time point in addition to the starting year and the ending year. The Moran Scatter Map of Forestry Total Factor Productivity of 30 regions could be gained by using the software ArcGIS after the Moran scatter plot had been created by taking advantage of the software GeoDa.

As seen in Fig. 2, in 1997-1998, the regions of high Forestry Total Factor Productivity, such as Liaoning, Jiangsu, Zhejiang, Fujian, Jiangxi and Guangdong provinces, located in the northeastern and southeastern China and accounted for 20% in all the provinces. By contrast, the regions of low Forestry Total Factor



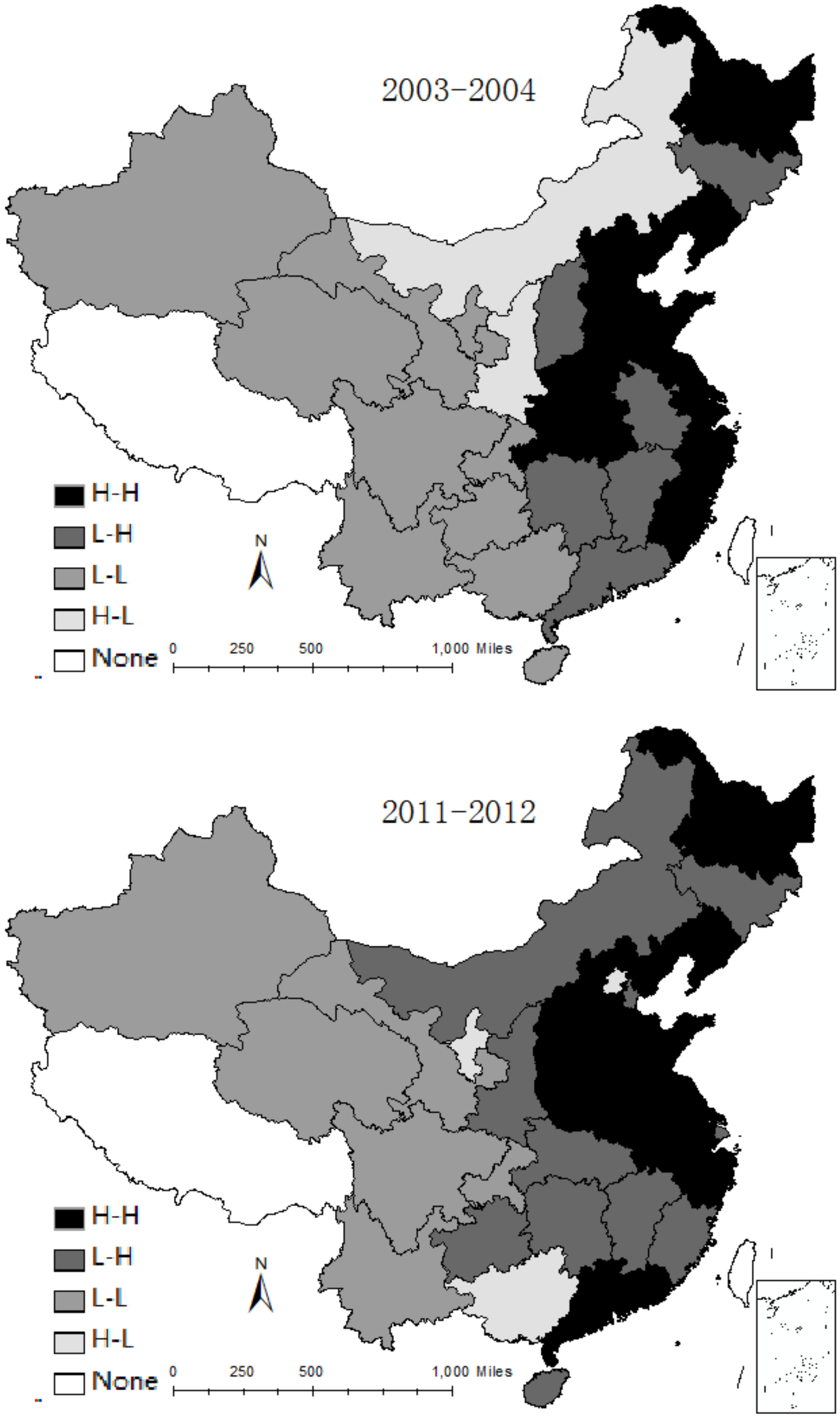


Fig. 2: The scatter maps of local spatial autocorrelation of forestry total factor productivity by provinces in China

Productivity, such as Gansu, Qinghai, Shaanxi, Sichuan, Guangxi, Hainan and Shanghai, were situated in the western China and accounted for 23.3%. These two types accounted for 43.3% in all four types. Therefore, this figure revealed that the distribution of Forestry Total Factor Productivity in China had presented a binary space structure, namely the regions of high Forestry Total Factor Productivity were mainly situated in some provinces of northeastern China and southeastern coastal regions, while the provinces of low Forestry Total Factor Productivity were mainly situated in western China. In addition, the fact that there were 14 provinces in the Transition Zone, accounting for 46.7%, showed that the Forestry Total Factor

Productivity in China was low in 1997-1998. Specifically, the provinces in the Transition Zone, including Heilongjiang, Jilin, Inner Mongolia, Hebei, Beijing, Tianjin, Shanxi, Shandong, Ningxia, Henan, Anhui, Hubei, Chongqing and Guizhou, were mainly distributed in the northern regions and central regions. By contrast, the Polarization Effect Zone, mainly including Xinjiang, Yunnan and Hunan, accounted for a small proportion in total.

Compared with 1997-1998, the number of provinces in the region of high Forestry Total Factor Productivity reached 12 provinces, including Heilongjiang, Liaoning, Hebei, Tianjin, Shandong, Jiangsu, Henan, Hubei, Shanghai, Zhejiang, Fujian and Beijing provinces, accounting for 40% of all 30 research provinces in 2003-2004. Furthermore, from the point of distribution, Heilongjiang entered into this zone, while the other provinces moved from the southeastern coastal regions into the northern regions. Moreover, there was a little increase in the regions, where low Forestry Total Factor Productivity was low compared with 1997-1998. The specific provinces mainly included Xinjiang, Gansu, Qinghai, Ningxia, Sichuan, Chongqing, Guizhou, Yunnan, Guangxi and Hainan. Therefore, we can know that this zone was mainly situated in western China and the scale had widened. The fact that the proportion of both kinds of regions was up to 73.3% proved that the binary space structure became more obvious in 2003-2004. Namely, the regional distribution of high Forestry Total Factor Productivity mainly located in the northeastern, the northern and the eastern coastal regions, while the regional distribution of low Forestry Total Factor Productivity mainly located in western China. In addition, the Transition Zone, including 6 provinces, moved to the Huabei and Huazhong regions and the Polarization Zone came to be distributed in Inner Mongolia and Shaanxi from the state of scattered distribution.

In 2011-2012, there was a little decrease with only 10 provinces of high Forestry Total Factor Productivity existing in the Diffusion Effect Zone, accounting for 33.3% in all the provinces. Specifically, they were Heilongjiang, Liaoning, Hebei, Henan, Shaanxi, Shandong, Jiangsu, Anhui, Zhejiang and Guangdong provinces. Compared with 2003-2004, the location of the provinces of high productivity moved to Huabei province except for the provinces that were situated in northeastern China in 2003-2004. The number of provinces of low Forestry Total Factor Productivity has been reduced to 6 provinces compared to 2003-2004, including Xinjiang, Gansu, Qinghai, Szechwan, Chongqing and Yunnan, accounting for 20% in all provinces. Therefore, the proportion of provinces that had a positive relationship was 53.3% in 2011-2012, which was a little decrease compared with 73.3% in 2003-2004. Namely, the binary structure of spatial distribution of Forestry Total Factor Productivity in China weakened from 2003-2004 to 2011-2012. In 2011-2012, the Transition Zone of Forestry Total Factor Productivity contained 11 provinces, accounting for 36.7% and it mainly concentrated in the central region of China. In 2011-2012, the Polarization Effect mainly contained Beijing, Ningxia and Guangxi and the distribution was relatively scattered.

Space-time transitions analysis: Space-time Transitions Analysis, by which the *Local Moran's I* could be divided into four types, is used to analyze the regional space variation of Forestry Total Factor Productivity in China. The first type, including $HH_t \rightarrow LH_{t+1}$, $HL_t \rightarrow LL_{t+1}$, $LH_t \rightarrow HH_{t+1}$, $LL_t \rightarrow HL_{t+1}$, is shown by the provinces of high Forestry Total Factor Productivity transferring to the lowers or the provinces of low Forestry Total Factor Productivity transferring to the higher, with their neighbors not changing any more. Based on the first type, the second type is shown by the provinces of high or low Forestry Total Factor

Table 2: The results of space-time transitions analysis

		1997-1998→2003-2004	2003-2004→2011-2012
First type	$HH_t \rightarrow LH_{t+1}$	Jiangxi, Guangdong	Fujian, Tianjin, Hubei, Shanghai
	$LH_t \rightarrow HH_{t+1}$	Heilongjiang, Hebei, Beijing, Tianjin, Shandong, Henan, Hubei	Guangdong, Shanxi, Anhui
	$LL_t \rightarrow HL_{t+1}$	Shaanxi	Ningxia, Guangxi
	$HL_t \rightarrow LL_{t+1}$	Xinjiang, Yunnan	—
Second type	$HH_t \rightarrow HL_{t+1}$	—	Beijing
	$LH_t \rightarrow LL_{t+1}$	Ningxia, Chongqing, Guizhou	—
	$LL_t \rightarrow LH_{t+1}$	—	Guizhou, Hunan
	$HL_t \rightarrow HH_{t+1}$	—	—
Third type	$HH_t \rightarrow LL_{t+1}$	—	—
	$LH_t \rightarrow HL_{t+1}$	Inner Mongolia	—
	$LL_t \rightarrow HH_{t+1}$	Shanghai	—
	$HL_t \rightarrow LH_{t+1}$	Hunan	Inner Mongolia, Shaanxi
Fourth type	$HH_t \rightarrow HH_{t+1}$	Liaoning, Jiangsu, Zhejiang, Fujian	Liaoning, Jiangsu, Zhejiang, Heilongjiang, Hebei, Shandong, Henan
	$LH_t \rightarrow LH_{t+1}$	Shanxi, Anhui, Jilin	Jiangxi, Hunan, Jilin
	$LL_t \rightarrow LL_{t+1}$	Gansu, Qinghai, Szechwan, Guangxi, Hainan	Chongqing, Gansu, Qinghai, Szechwan, Xinjiang, Yunnan
	$HL_t \rightarrow HL_{t+1}$	—	—

Productivity transferring to the opposite and their neighbors also changing. This type mainly includes $HH_t \rightarrow HL_{t+1}$, $HL_t \rightarrow HH_{t+1}$, $LH_t \rightarrow LL_{t+1}$, $LL_t \rightarrow LH_{t+1}$. The third type, including $HH_t \rightarrow LL_{t+1}$, $HL_t \rightarrow LH_{t+1}$, $LL_t \rightarrow HH_{t+1}$, $LH_t \rightarrow HL_{t+1}$, is shown by the provinces of high or low Forestry Total Factor Productivity and their neighbors transferring to the opposite. The fourth type is shown by the provinces that do not change all the time and it includes $HH_t \rightarrow HH_{t+1}$, $HL_t \rightarrow HL_{t+1}$, $LH_t \rightarrow LH_{t+1}$, $LL_t \rightarrow LL_{t+1}$.

Table 2 shows the results of Space-time Transitions Analysis of 30 provinces. As seen in the table, from 1997-1998 to 2003-2004, 40% provinces are located in the first type, of which the majority are located in the type of $LH_t \rightarrow HH_{t+1}$ and the other 40% provinces are located in the fourth type. Therefore, we can know that there are two kinds of characteristics about the variation of Forestry Total Factor Productivity during the research time. Namely, some provinces presented a variation trend toward high Forestry Total Factor Productivity and the others presented a stable phenomenon. Furthermore, from 2003-2004 to 2011-2012, there were 16 provinces in the fourth type and the provinces that transfer from high or low Forestry Total Factor Productivity to their own state had the largest percentage in this type. Therefore, in this period, the majority in all provinces showed a characteristic of stability. Specifically, the regions of high Forestry Total Factor Productivity were represented by Liaoning, Jiangsu and Zhejiang provinces, while the lowers were represented by Gansu, Qinghai and Sichuan.

DISCUSSION

First, China's forestry policy had a great effect on the spatial distribution of the Forestry Total Factor Productivity. The Natural Forest Protection Program, which was mainly carried out in western China, 12 provinces and beginning from 1998, resulted in a decline in the forestry output. Therefore, this policy led to the phenomenon that the convergence of low Forestry Total Factor Productivity mainly appeared in western China to a certain extent. In 2002, the Sloping Land Conversion to Forest or Grass Coverage Program, which was also mainly implemented in western China, was carried out thoroughly. Although this program promoted the increase of afforestation area, the ban on logging, which had a series of restrictions on the forestry output and the increasing forestry input of investment and labor, exacerbated the convergence of provinces further that were of low Forestry Total Factor Productivity in western China. In 2003, several provinces in eastern China took the lead to carry out the Collective Forest Tenure Reform that promoted the development of the regional forestry economy. Furthermore, this program made the forestry economy in eastern China develop faster than in western China, especially the forestry policy of *The Opinions on Pushing Forward the Collective Forestry Tenure Reform Comprehensively*, which was issued in 2008. Along with the implementation of this policy, the farmers' enthusiasm for forestry production was stimulated and the attached policies, such as the forestry tenure mortgage, forest insurance, forestry cooperation organization, etc, were implemented first in eastern China. Therefore, this resulted in the convergence of high Forestry Total Factor Productivity in eastern China. At the same time, the policy on the Natural Forest Protection Program Ⅱ, in effect from 2011 to 2020, was carried out in 2008. Therefore, this led to the convergence of low Forestry Total Factor Productivity in western China further.

Second, technology change is also an important factor that determines the spatial distribution and its evolution. Through econometric analysis, we found that technology change lowered the Forestry Total Factor Productivity in China; however, the technology is not reversible, generally. Therefore, the inhibitory effect caused by technology change on the Forestry Total Factor Productivity is mainly caused by the insufficient technology investment and the transformation of technology direction rather than the revensal decline backward progress of forestry technology. Inadequate investment in forestry science and technology in China have existed for a long time. For example, the forestry investment in science and technology in 2012 accounted for 0.26% of all forestry investment. Thus, the forestry technology did not play an important role in the increase of Forestry Total Factor Productivity. In addition, the development of forestry science and technology in China is close to the existing strategy and planning of national forestry development. In recent years, the forestry development in China has improved greatly due to the change in development direction change from the excessive deforestation to the forestry ecological construction and protection. Such programs include the Porgram of Shelterbelt Network in North, the Northwest and Northeast China, the Wildlife protection and Nature Reserve Construction, Natural Forest Protection Program, Sloping Land Conversion to Forest or Grass Coverage Program. As a result, the developing direction of science and technology also gradually changed from the technology of deforestation and transport equipment research to other fields that resulted in low forestry output, such as the forest tending, soil and water conservation, wetland restoration, etc. Furthermore, the fact that the construction of forestry ecological projects are widely implemented in western China resulted in the western provinces always being situated in the zone of low Forestry Total Factor Productivity.

The distribution features of forestry resources in China determined the spatial characteristics of the Forestry Total Factor Productivity. The forestry output is close to the endowment and distribution of forestry resources. Currently, the forest area in China, 195.4522 million hectares, is ranked fifth and the forest volume, 13.721 billion cubic meters, is ranked sixth in the world, respectively. However, in terms of per capita level, the per capita forest area in China is less than a quarter of the world's per capita and the per capita forest volume is only 1/7 of the world's per capita. The poor forestry resources in China restrain China's forestry output. The distribution of forestry resources is extremely uneven due to the geographical conditions, natural disasters, etc. Specifically, the northeastern provinces in China have the highest forest coverage rate, 40.22%, compared with the western provinces where the forestry coverage rate is only 17.05% but the area accounts for 54.27% in China. Therefore, this distribution caused the Forestry Total Factor Productivity in China to present a different distribution. For example, with the advantage of rich forestry resources, Heilongjiang and Liaoning presented the convergence phenomenon of high Forestry Total Factor Productivity. Comparatively, Gansu and Qinghai, which lack forestry resources for forestry production, presented the convergence phenomenon of low Forestry Total Factor Productivity.

Furthermore, the imbalanced development of regional economy in China is another main reason that causes the binary spacial distribution of Forestry Total Factor Productivity. The development of forestry industry that has a close relationship with other industries is restricted greatly by other economic sectors. For example, Xinjiang, Qinghai and Gansu, the western provinces in China, showed a convergence trend of low Forestry Total Factor Productivity because they have not only poor forestry resources but also weak economic development, which could not promote the development of the forestry industry. Yunnan, which has rich forestry resources, is weak in terms of economic development. Therefore, it is also situated in the convergence zone of low Forestry Total Factor Productivity. Comparatively, for the eastern coastal provinces in China, various industries can effectively promote the development of forestry industry because of the better economy. Thus, this fact contributes to high forestry output and resulted in the convergence phenomenon of high Forestry Total Factor Productivity.

CONCLUSION

This study calculates the Forestry Total Factor Productivity of 30 provinces in China and analyzes its temporal-spatial evolution by using the Malmquist analysis, global spatial autocorrelation and local spatial autocorrelation, with the support of software DEAP2.1, GeoDa and ArcGIS. The results show as follow:

First, the Forestry Total Factor Productivity in China shows the phenomenon of obvious fluctuations from 1997 to 2012 mainly due to the technology change.

Second, there were two characteristics of spatial distribution on Forestry Total Factor Productivity in China from 1997 to 2012. It showed a phenomenon of discrete distribution from 1997 to 2003 and showed a phenomenon of convergence distribution from 2003 to 2012.

Third, from the view of local spatial variation of Forestry Total Factor Productivity in China, it presented an obvious binary space structure from 1997 to 2012. In 1997-1998, the provinces of high Forestry Total Factor Productivity were mainly situated in the northern and southeastern China, while the lowers in western China. In 2003-2004, the provinces of high Forestry Total Factor Productivity moved to northern China and eastern coastal provinces gradually and the lowers were still situated in western China. In 2011-2012, the provinces of high Forestry Total Factor Productivity moved to northern China further and the lowers did not change to a large extent, but the spatial distribution of binary structure had weakened. As a whole, the zone of high Forestry Total Factor Productivity moved to the north gradually, including Shandong, Jiangsu and Zhejiang and the lowers were situated in the western China, including Gansu, Qinghai and Szechwan.

Fourth, from the view of local spatial variation of Forestry Total Factor Productivity in China, the spatial pattern of the majority in 30 provinces showed the characteristics of stability in this 16-year period. From 1997-1998 to 2003-2004, parts of the provinces presented a convergence transition phenomenon of high Forestry Total Factor Productivity while the others kept stable. From 2003-2004 to 2011-2012, the majority showed a phenomenon that the provinces of high Forestry Total Factor Productivity moved to the same types, namely the spatial pattern of Forestry Total Factor Productivity showed the characteristics of stability.

Fifth, from the perspective of the variation motivation of Forestry Total Factor Productivity in China, the main reasons for the current spatial distribution pattern are forestry policy disparities, inadequate input of forestry technology, the direction change of forestry science and technology, the imbalanced distribution of forestry resources and the regional economic development.

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