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Speed and Contribution of Educational Scientific and Technological Progress in Development of Primary Forestry Industry in China

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ABSTRACT

Our purpose is to analyse the speed and contribution of the educational scientific and technological progress in the development of the primary forestry industry. In order to research the role of the educational scientific and technological progress in the development of the primary forestry industry more scientifically, the article employs the modified multi-factor two-level CES production function model, and the data from 31 provinces over 19 years (1994-2012), to measure and calculate the speed and contribution of the educational scientific and technological progress in the development of the primary forestry industry from the two dimensions, time and space. The speed of educational scientific and technological progress in the primary forestry industry was 2.8% from 1994 to 2012, and the contribution rate of educational scientific and technological progress to the development of the primary forestry industry was 49.6%. Through the measuring and calculating of different periods, it is found that there were big differences between different periods regarding to the contribution of the educational scientific and technological progress to the development of the primary forestry industry, and the contribution grew quickly in the last few years. Through the measuring and calculating of different areas, it is found that there were huge differences between different areas regarding to the contribution of the educational scientific and technological progress to the development of the primary forestry industry, due to the difference in nature, society and economic environment. Along with the development of the economy, the structure of the forestry industry needs important changes. The dominating status of the primary forestry industry in the forestry industry should be strengthened. The educational science and technology investment of the primary forestry industry should be boosted, to lead the development of the primary forestry industry onto a path relying on the progress of educational science and technology. In the process of making the development policy and investment policy on the primary forestry industry, it shall not impose uniformity in all cases. On the contrary, the policy shall vary according to the different situations; and it is noticed that

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State of the literature

- Early empirical studies explored the impact of educational science and technology progress on forestry development. It is conclusion that educational science and technology progress have greatly contributed to the development of China's forestry.
- These studies performed comparative analysis on different regions, or these studies conducted time-series studies, and believed that educational science and technology progress played a positive role in the development of the forestry in different periods or in different regions.
- Earlier researchers largely adopted basic statistical description methods, and in recent years researchers have used more non-parametric estimation to measure the contribution of educational science and technology progress to the forestry production.

Contribution of this paper to the literature

- There are huge differences between the primary industry of forestry and the secondary and tertiary industries, but current studies rarely differentiated them. This paper conducts analysis on the speed and contribution of educational science and technology progress in the primary forestry industry.
- There are few studies on the contribution of educational science and technology progress in the forestry both in temporal and spatial perspectives. This paper conducted research in the time-space dimension using the panel data from 31 provinces or municipalities in China between 1994 and 2012.
- This paper developed a research method of a modified multi-factor two-level CES production function to analysis on the speed and contribution of educational science and technology progress in the primary forestry industry.

the comparative advantages of different areas with different social economic and natural resources shall be exerted.

Keywords: development of the primary forestry industry, educational scientific and technological progress, speed and contribution, temporal and spatial differentiation

INTRODUCTION

Along with the development of the economy, ecological civilization construction is attracting increasing attention from all sectors in China. The CPC Central Committee and the State Council introduced the Opinions of the CPC Central Committee and the State Council on Accelerating the Ecological Civilization Construction (Zhong Fa [2015] No.12), laying out a comprehensive plan for advancing ecological civilization construction. As a carrier for ecological protection and construction, the primary forestry industry plays a crucial role in the ecological civilization construction in China. It, including forestation, forest management, and forest tending, is essential with the growth and stock volume of forests and is important to beautifying the environment and eliminating pollution. Its sustainable development, therefore, is fundamental for environmentally friendly and healthy development of the Chinese economy. There are only two ways to keep China’s primary forestry industry develop in a sustainable manner: the first way is to input plenty of production factors for the forestry for extensive production; the second is to rely on the progress in the forestry educational science and technology for intensive production. Since 1999, when China implemented ecological returning of farmland on a large scale, the factor input in the primary forestry industry has surged: the annual area for ecological returning of farmland in China between 2000 and 2005 were 1271.9 km2. The primary forestry industry developed greatly thanks to vast input of production factors, with rapid increase in the forest coverage rate and forest stock in unit area, especially in the east part of China, and strengthened ecological function of the forest. However, as China’s industrialization and urbanization develop rapidly, the comparative income of the forestry production drops gradually, the rural labor force in mountain areas moves out, and the enthusiasm of peasants to input labor and capital factors in the primary forestry industry fades away. Meanwhile, China's ecological returning of farmland reaches a protection and consolidation phase, the growth of land input in the primary forestry industry decreases rapidly, making it difficult to sustain its development in an extensive way relying on vast input. So, the input of educational technological factors will eventually become a crucial means to maintain the sustainable development in the primary forestry industry and strengthen the ecological service function of the forestry. At what speed was the educational science and technology in the production of the primary forestry industry in China advancing? How much did the educational technological factors contribute? The in-depth, systematic analyses on these problems are of great practical significance.

According to the document retrieval, studies on the role of educational science and technology in forestry production by researchers at home and abroad can be summarized as follows. First, in terms of the study contents: the significance and role of educational scientific and technological progress on the forestry development were analysed, among which, Fan(1991) considered though educational scientific and technological progress promotes the development of the forestry to a certain extent, the development relies more on the input of factors due the growth nature of forests, some other scholars, like Feng and Qiu (2009) and Nowak et al. (2016),have a similar views, but more scholars, like Lei (1996), , He (2012), Huang et al. (2012), Hu and He (2012), Jiang et al. (2012), Kong et al. (2014), Liu (2017), Hashem A. (2016), considered that educational scientific and technological progress have greatly contributed to the development of China's forestry. Second, in terms of the time-space dimension: comparative analysis on different regions were performed. Liu et al. (1996) concluded that there were significant differences in educational scientific and technological progress of the forestry production between different regions. More researchers, like Fan (1991), Nakamura H. & Nakamura M. (2008), Li and Pan (2008) Wang and Huang (2006) Wang (2002), Wei et al. (2012) and Wu and Lin (2007) , Gao et al. (2017) conducted time-series studies, and believed that educational scientific and technological progress played a positive role in the development of the forestry in all periods, with increased role over time, among which some, like Wang and Huang (2006), Wu et al. (2007), Yan and Jiang (2002) and Zhang (1990), carried out staged analyses by comparing the contribution of educational scientific and technological progress in the development of the forestry in the "8th five-year", "9th five-year" and "10th five-year" periods. Third, in terms of study objects, because of the availability of data, individual regions or individual time points were studied (Fan(1991); Feng and Qiu, 2009; He et al., 2012; Huang et al., 2012; Hu and He, 2012; Liu and Liu, 2010; Jiang et al., 2012; Liu et al., 2014; Li and Pan, 2008; Wang and Huang, 2006; The People's Republic of China Yearbook Background, 1999), and there are few studies on comparative analysis of both different regions and different time points. Fourth, in terms of research methods, earlier researchers largely adopted basic statistical description methods to analyse the relation between educational scientific and technological progress and forestry development, and in recent years researchers have used more non-parametric estimation (Kong et al., 2014; Lei, 1996; Kao and Yang, 1991), such as data envelopment analysis (DEA) and C-D production function based parameter estimation (Dong and Sun, 2007; Feng and Qiu, 2009; Huang et al., 2012; Mi et al., 2014; Kao and Yang, 1992), to measure the contribution of educational scientific and technological progress to the forestry production, and Wang (2002) and Kao and Yang(1992), Mi et al. (2015) have summarized research methods.

To sum up, Chinese and foreign researchers have conducted studies on the role of educational scientific and technological progress in the forestry development, and produced many beneficial conclusions, which lays a good foundation for the analysis in this paper. However, there is still room for theoretical study on the effect of educational scientific and technological progress in the forestry development to expand and develop in the following aspects, according to the results of literature review: first, in terms of research contents, the relatively consistent conclusion is that educational scientific and technological progress plays an import role in the development of the forestry; however, there are huge differences between the primary industry of forestry and the secondary and tertiary industries, but current studies rarely differentiated them and there is a lack of the study dedicated on the contribution of educational scientific and technological progress to the primary forestry industry. Second, in terms of research dimensions, there are few studies on the contribution of educational scientific and technological progress in the forestry both in temporal and spatial perspectives. Third, in terms of research methods, the DEA only measures the relative technological efficiency but not the contribution of technological progress, and the C-D function calculates the contribution of technological progress by employing Solow residual, which will result in big deviation because the stage of the primary forestry industry and involvement of non-technological factors. Therefore, this paper conducts analysis on the speed and contribution of educational scientific and technological progress in the primary forestry industry in the time-space dimension by taking the primary forestry industry as the object, considering the stage of the primary forestry industry, developing a modified multi-factor two-level CES production function, and using the panel data from 31 provinces or municipalities in China between 1994 and 2012. Next, the paper will deal with the following contents: (1) model setting and data sources: to develop the model for analysis and measure and introduce data sources and processing; (2) empirical results and analysis: to introduce the results from measurement of the developed model, and conduct analysis; (3) conclusions and inspiration.

MATERIAL AND METHODS

Methods

In order to evaluate the speed and contribution of educational scientific and technological progress in the development of the primary forestry industry, based on relative theoretical studies, and taking into account two stages of the forestry production, afforestation and follow-on production, this paper developed a modified multi-factor two-level CES production function model:

$$O_{it1} = (\chi_1 E_{it}^{-\varphi_1} + \chi_2 W_{it}^{-\varphi_1})^{\frac{1}{\varphi_1}} \quad (1)$$

$$O_{it} = \lambda e^{vt} (\chi_3 O_{it1}^{-\varphi} + \chi_4 T_{it}^{-\varphi})^{-\frac{n}{\varphi}} \quad (2)$$

In equation (1), i represents the region, i=1, 2, 3, ..., 31. t represents the year, t= 1994, 1995, ..., 2012. O_{it1} represents the function value of the first stage. E_{it} represents the land input in the development of the primary forestry industry in region i in t year, and W_{it} represents the labor input in the primary forestry industry. χ_1 and χ_2 are the influence coefficient for the capital input and land input on the development of the primary forestry industry, which are solve-for parameters, and φ_1 represents the partition coefficient. In equation (2), O_{it} represents the production value of the primary forestry industry in region i in t year, T_{it} represents the capital input in the development of the primary forestry industry in Region i in t year, λ represents the comprehensive benefit coefficient, v represents the speed of educational scientific and technological progress, λe^{vt} represents the multiple of production value caused by generalized technological level, χ_3 and χ_4 represent the influence coefficients of the input factors in the second stage of the modified two-level CES production function, and φ represents the partition coefficient. n is the coefficient for returns to scale, when $n > 1$, the development of the forestry has increasing returns to scale, and when $n < 1$, the primary forestry industry has a decreasing return to scale, and when $n = 1$, the return to scale of is constant.

Since equations (1) and (2) are nonlinear functions, Taylor series expansion is used for logarithm linearization to facilitate estimation. First, take the logarithm for equations (1) and (2) and obtain equation (3) and (4):

$$\ln O_{it1} = \frac{1}{\varphi_1} \ln(\chi_1 E_{it}^{-\varphi_1} + \chi_2 W_{it}^{-\varphi_1}) \quad (3)$$

$$\ln O_{it} = \ln \lambda + vt - \frac{n}{\varphi} \ln(\chi_3 O_{it1}^{-\varphi} + \chi_4 T_{it}^{-\varphi}) \quad (4)$$

Next, process the term of $\ln(\chi_3 O_{it1}^{-\varphi} + \chi_4 T_{it}^{-\varphi})$ of equation (4) by expanding Taylor-series at $\varphi = 0$ and keep terms of orders 0, 1 and 2, and the expansion can be arranged and simplified as:

$$\ln O_{it} = \ln \lambda + vt + \chi_3 n \ln O_{it1} + \chi_4 n \ln T_{it} - \frac{1}{2} \varphi n \chi_3 \chi_4 \left(\ln \frac{O_{it1}}{T_{it}} \right)^2 \quad (5)$$

Similarly, equation (1) is processed in like manner: expand Taylor-series at $\varphi_1 = 0$, yielding the approximate expression of O_{it1}:

Table 1. Corresponding relation of constant and coefficient

Solve-for parameter	z_0	z_1	z_2	z_3	z_4	z_5	z_6
Corresponding coefficient	$\ln\lambda$	v	$n\chi_1\chi_3$	$n\chi_2\chi_3$	$n\chi_4$	$-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1$	$-\frac{1}{2}n\chi_3\chi_4\varphi$
Variable code	Constant term	X_{it}^1	X_{it}^2	X_{it}^3	X_{it}^4	X_{it}^5	X_{it}^6
Corresponding variable	Constant term	t	$\ln(E_{it})$	$\ln(W_{it})$	$\ln(T_{it})$	$\ln^2(E_{it}/W_{it})$	$\ln^2(E_{it}/T_{it})$

Note: $\chi_1+\chi_2=1$, $\chi_3+\chi_4=1$

$$\ln O_{it1}=\chi_1\ln E_{it}+\chi_2\ln W_{it}-\frac{1}{2}\varphi_1\chi_1\chi_2\left(\ln\frac{E_{it}}{W_{it}}\right)^2 \tag{6}$$

Substituting equation (6) into equation (5), arranging and adding a stochastic error term μ_{it}, gives the final econometric model for analysis of regression:

$$\ln O_{it}=\ln\lambda+vt+n\chi_1\chi_3\ln E_{it}+n\chi_2\chi_3\ln W_{it}+n\chi_4\ln T_{it}-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1\left(\ln\frac{E_{it}}{W_{it}}\right)^2-\frac{1}{2}n\chi_3\chi_4\varphi\left(\ln\frac{E_{it}}{T_{it}}\right)^2+\mu_{it} \tag{7}$$

It can be found from equation (7), there are non-linear relationships between the development of the primary forestry industry and the input elements. To help estimate by using classical econometric approaches, linear variable substitution is applied. Equation (7) is transformed as following:

$$\ln O_{it}=z_0+z_1X_{it}^1+z_2X_{it}^2+z_3X_{it}^3+z_4X_{it}^4+z_5X_{it}^5+z_6X_{it}^6+\varepsilon_{it} \tag{8}$$

The corresponding relations between equations (7) and (8) are shown in **Table 1**.

The parameters in equation (8) can be estimated by using econometric approaches, so the values of the parameters in equation (7) can be obtained. Together with (9), this can be used to measure the contribution rate of the educational scientific and technological progress to the development of the primary forestry industry:

$$D_{it}=\frac{v_{it}}{R_{it}}\times100\%=\frac{v_{it}}{\sqrt[n]{\frac{O_{it_n}}{O_{it_0}}}-1}\times100\% \tag{9}$$

In equation (9), D_{it} is the contribution rate of the educational scientific and technological progress to the development of the primary forestry industry in Region i in t year, v_{it} is the speed of educational scientific and technological progress of the primary forestry industry in Region i in t year, and R_{it} is the average growth rate of the primary forestry industry in Region i in t year. Take t_0 as the base period for calculation, O_{it_0} is the production value of the primary forestry industry in Region i in base period, and O_{it_n} is that in Region i in the report period.

Material Indexes and Data

Selecting appropriate input and output indexes are key to accurately measuring the speed and contribution rate of educational scientific and technological progress in the development of the primary forestry industry. For the output of the primary forestry industry, O_{it}, the values before 2001 are provided from macro-statistics, and there is no data after 2001; this paper, therefore, uses the sum of the values of forest culture and planting, and harvesting of lumber and bamboo wood of the primary forestry industry for estimation. For the input factor indexes, the forest land area is used as the land factor in the development of the primary forestry industry, E_{it}; since the forest land area was not updated every year, the forest land area from the 5th-8th national forest inventories are used in this paper to correct the land area between 1994 and 2012. The difference between the completed investment on fixed assets of the forestation of the previous period and that of the next period, together

Table 2. Descriptive statistics of the variables

Variable/alternate variable		Number of samples	Mean	Standard Deviation	Min	Max
Dependent variable	$\ln(O_{it})$	587	11.901	1.281	6.522	14.383
Independent variable	t/X_{it}^1	587	10.029	5.469	1	19
	$\ln(E_{it})/X_{it}^2$	587	6.309	1.416	0.811	8.390
	$\ln(W_{it})/X_{it}^3$	587	9.720	1.282	4.522	13.404
	$\ln(T_{it})/X_{it}^4$	587	10.428	1.664	6.282	13.606
	$\ln^2(E_{it}/W_{it})/X_{it}^5$	587	12.964	7.658	0.005	91.238
	$\ln^2(E_{it}/T_{it})/X_{it}^6$	587	3.609	4.591	0.000	26.948

Note: the output level, land factor (E), capital input factor (T), labor factor (W), and time (t) included in the table are expressed in 10,000 yuan, 10,000 hectares, 10,000 yuan, person and year. The same hereinafter.

Table 3. The results of unit root test

Variable	Testing method	Testing basis	Statistic	Significance	Result
O, E, W, T	Levinlin test	Original sequence	-22.14457	0.0000	Stationary
	hadri test	Original sequence	37.0047	0.0000	

Note: The null hypothesis for unit root test is that the presence of a unit root, which means the data units are non-stationary.

with the sum of seeding costs and pesticides and chemical fertilizers expenses used in forestation, is used as the capital input, T_{it}, of each year; the average of the value of 1995 and 1997 is used as the value of 1996, due to missing data. The year-end number of employees engaged in the primary forestry industry is used the labor input in the primary forestry industry W_{it}. The data are from China Forestry Statistics (1995-1997), China Forestry Statistical Yearbook (1998-2013) and China Statistical Yearbook (1995-2013) and the 5th-8th National Forest Inventories. All output values and capital input values are converted by using price conversion index with 1994 as the base period. **Table 2** shows the descriptive statistics of all variables for input and output data estimation:

RESULTS AND DISCUSSION

Unit Root Test

To prevent spurious regression in analysis of panel data, testing for stationary is conducted for the data and the results of unit root test in the panel data are shown in **Table 3**. According to the results, all index data used in the paper are stationary at the same order and can be used for econometric regression estimation and corresponding analysis.

Overall Results and Discussion

First, the data of 19 years from 31 provinces and municipalities are used for global estimation. There are three models for parameter estimation by using panel data, the hybrid effect, fixed effect, and random effect models. Wald testing and Hausman testing are used to select the estimation model, and the results are shown in **Table 4**, indicating the optimal model is the fixed effect model.

The values of the parameters of the modified multi-factor two-level CES function (shown in **Table 5**), can be obtained by using the parameters estimated in the fixed effect model in **Table 4**, together with **Table 1**, followed by estimation of the modified two-level CES production function. According to **Table 5**, the speed of educational scientific and technological progress in the primary forestry industry between 1994 and 2012 was 2.8%; the output value of the primary forestry industry in 1994 and 2012 was 46.43032 billion yuan and 124.57720 billion yuan, respectively so it can be obtained the annual growth rate was 5.64%. Thus, the contribution rate of the educational scientific and technological progress was 49.6% according to equation (9).

Table 4. The results of the global estimation of the model

Variable	Solve-for parameter	Hybrid model		Fixed effects model		Random effects model	
		Coefficient	T value	Coefficient	T value	Coefficient	T value
X_{it}^{1}	z_1	0.043***	3.80	0.028***	4.51	0.030***	4.81
X_{it}^{2}	z_2	0.060	0.67	0.580***	3.83	0.379***	3.86
X_{it}^{3}	z_3	0.721***	11.41	0.168***	3.82	0.191***	4.36
X_{it}^{4}	z_4	-0.090	-1.14	0.090**	2.12	0.081*	1.90
X_{it}^{5}	z_5	-0.041***	-4.37	-0.014**	-2.47	-0.016**	-2.85
X_{it}^{6}	z_6	0.021**	2.48	0.004	0.84	0.006	1.29
Sample size		589		589		589	
R^2		0.4930		0.4945		0.3904	
F/wald chi2		93.99		72.02		546.54	
Model selection test							
Wald test		P=0.00					
Hausman test		P=0.00					

Note: ***, **, and * represent the level of significance of 1%, 5% and 10%, respectively. The same hereafter.

Table 5. The contribution rate of educational scientific and technological progress through CES function

Estimated parameter	z_0	z_1	z_2	z_3	z_4	z_5		z_6	
Corresponding parameter	$\ln\lambda$	v	$n\chi_1\chi_3$	$n\chi_2\chi_3$	$n\chi_4$	$-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1$		$-\frac{1}{2}n\chi_3\chi_4\varphi$	
Estimated value	5.480	0.028	0.580	0.168	0.090	-0.014		0.004	
Single parameter	χ_1	χ_2	χ_3	χ_4	n	φ_1	φ	v_{it}	R_{it}	D_{it}
Estimated value	0.78	0.22	0.89	0.11	0.838	0.22	-0.10	2.8%	5.64%	49.6%

In addition, **Table 5** demonstrates that every input factor is positively correlated with the development of the primary forestry industry, be it the land, capital, or labor. According to the regression coefficient value, without change in the other conditions, the output value of the primary forestry industry is increased by 0.580% when the land input is increased by 1%, by 0.168% when the labor input is increased by 1%, and by 0.090% when the fixed assets input is increased by 1%, the elastic increment of the forest land area much larger than the other two input factors. The primary cause may be that China has a large population, the land is comparatively scarce; consequently, with the returning farmland to forests in China, the output efficiency from the land input was higher. In addition, the elasticity of substitution of land for labor was -0.014, indicating that the returning farmland to forests must be based on the increase of labor engaged in the primary forestry industry, due to the massive transfer of labor from the mountain regions in China nowadays.

Substituting the estimates from **Table 5** into equations (1) and (2) obtains the modified two-level CES production functions between 1994 and 2012 as shown in equations (10) and (11).

$$O_{it1} = \left(0.78E_{it}^{-0.22}0.22W_{it}^{-0.22}\right)^{4.55} \tag{10}$$

$$O_{it} = 2.72^{5.48}e^{0.028t}\left(0.89O_{it1}^{0.1} + 0.11T_{it}^{0.1}\right)^{8.38} \tag{11}$$

Staged Results and Discussion

The effect of the educational scientific and technological progress on the forestry production is susceptible to the natural environment and policy environment. During the catastrophic flood in China's three-river watershed

Table 6. The results of different time periods estimation

Variable	Solve-for parameter	1994-1998		1999-2007		2008-2012	
		Coefficient	T value	Coefficient	T value	Coefficient	T value
Constant term	z_0	12.654***	2.78	5.943***	4.45	7.707***	7.64
X_{it}^1	z_1	0.058*	1.83	-0.006	-0.52	0.020	0.88
X_{it}^2	z_2	-0.585	-0.79	0.904***	4.22	0.683**	2.50
X_{it}^3	z_3	0.263***	2.67	0.027	0.75	0.036	0.19
X_{it}^4	z_4	0.045	0.44	-0.033	-0.37	-0.105	-0.76
X_{it}^5	z_5	-0.054***	-4.05	-0.0003	-0.06	-0.002	-0.09
X_{it}^6	z_6	-0.010	-0.58	0.022**	2.35	0.026	1.61
Sample size		153		279		155	
R^2		0.1694		0.2514		0.3414	
F		29.34		83.29		33.02	
Wald test		P=0.00		P=0.00		P=0.00	
Hausman test		P=0.00		P=0.00		P=0.35	

in 1998, many forest lands were destroyed, resulting in a decrease in forest land area; the natural disaster may interfere with the effect of the educational scientific and technological progress on the primary forestry industry. The 19th meeting of the Standing Committee of the 10th National People's Congress of the People's Republic of China approved that the Regulations for the Agricultural Tax was to be abolished on January 01, 2006. In June 2008, the CPC Central Committee and the State Council introduced the Opinions of the Central Committee of the Communist Party of China and the State Council on Boosting the Reform of Collective Forest Right System in an All-round Way, requesting to basically complete the reform of clarification of property rights and household-based contracting in about five years, and increasing the subsidies for forestation and tending of woods. The implementation of these policies mobilized peasants greatly, which, naturally, affected the contribution of the educational scientific and technological progress in the forestry production (Lei, 1996). To further the analysis on the effect of changes in the natural environment and policy environment on the contribution of the educational scientific and technological progress in the primary forestry industry, this paper divides the period between 1994 and 2012 into three stages, i.e., 1994-1998, 1999-2007, 2008-2012, for comparative analysis on the contribution of the science and technology in the production of the primary forestry industry in China.

First, Wald testing and Hausman testing are employed to select the parameter estimation model. The testing results show that the fixed effect model is superior to the hybrid effect model for all three stages. Meanwhile, the fixed effect model is superior to the random effect model for stage 1 and stage 2, and is inferior for stage 3, so the fixed effect model is adopted for stages 1 and 2 and the random effect model is adopted for stage 3 for parameter estimation. The estimation results are shown in **Table 6**.

The values of the parameters of the modified multi-factor two-level CES function (shown in **Table 7**), can be obtained by using the parameters estimated in **Table 6**, together with **Table 1**, followed by estimation of the modified two-level CES production function. **Table 7** shows that the speed of the educational scientific and technological progress in the primary forestry industry in stages 1, 2, and 3 were 5.8%, -0.6%, and 2.0%, respectively, and the average growth rate of the output value of the primary forestry industry in stages 1-3 calculated from the statistics were 3.77%, 5.05% and 6.79 respectively. Accordingly, according to equation (9), the contribution rate of the educational scientific and technological progress was 153.8%, -11.8%, and 29.5%, respectively.

In stage 1, there was excessive contribution of the educational scientific and technological progress in the primary forestry industry. The reason may be that the catastrophic flood in 1998 brought about massive losses to the output value and fixed assets of the primary forestry industry, with decreased forest land area due to flooding, minimum increment of primary forestry output, and the average annual growth rate in the primary forestry industry was small, all together making the speed of the educational scientific and technological progress overpass the annual growth rate of the output of the primary forestry industry. In stage 2, the contribution of the educational

Table 7. The contribution rate of technological progress through CES function in different time periods

1994-1998	**Estimated parameter**	z_0	z_1	z_2	z_3	z_4	z_5			z_6	
	Corresponding parameter	$\ln\lambda$	v	$n\chi_1\chi_3$	$n\chi_2\chi_3$	$n\chi_4$	$-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1$			$-\frac{1}{2}n\chi_3\chi_4\varphi$	
	Estimated value	12.654	0.058	-0.585	0.263	0.045	-0.054			-0.010	
	Single parameter	χ_1	χ_2	χ_3	χ_4	n	φ_1	φ	v_{it}	R_{it}	D_{it}
	Corresponding value	1.8	-0.8	1.16	-0.16	-0.277	0.23	0.39	5.8%	3.77%	153.8%
1999-2007	**Estimated parameter**	z_0	z_1	z_2	z_3	z_4	z_5			z_6	
	Corresponding parameter	$\ln\lambda$	v	$n\chi_1\chi_3$	$n\chi_2\chi_3$	$n\chi_4$	$-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1$			$-\frac{1}{2}n\chi_3\chi_4\varphi$	
	Estimated value	5.943	-0.006	0.904	0.027	-0.033	-0.0003			0.022	
	Single parameter	χ_1	χ_2	χ_3	χ_4	n	φ_1	φ	v_{it}	R_{it}	D_{it}
	Corresponding value	0.97	0.03	0.95	0.05	0.976	0.02	-0.95	-0.6%	5.05%	-11.8%
2008-2012	**Estimated parameter**	z_0	z_1	z_2	z_3	z_4	z_5			z_6	
	Corresponding parameter	$\ln\lambda$	v	$n\chi_1\chi_3$	$n\chi_2\chi_3$	$n\chi_4$	$-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1$			$-\frac{1}{2}n\chi_3\chi_4\varphi$	
	Estimated value	7.707	0.020	0.683	0.036	-0.105	-0.002			0.026	
	Single parameter	χ_1	χ_2	χ_3	χ_4	n	φ_1	φ	v_{it}	R_{it}	D_{it}
	Corresponding value	0.95	0.05	1.17	-1.17	0.614	0.12	0.43	2.0%	6.79%	29.5%

scientific and technological progress was negative. The major reason lies in that between 1999 and 2007, China witnessed a rapid urbanization, and many peasants moved into cities for work by leaving farming and forestry, so fewer people managed forests, and the human costs for the forestry rose. Many forests were recovering from the damage caused by the flood in 1998. Moreover, few peasants made investments in the forestry due to low prices of wood, leaving forests grow naturally. All these set back the input in the science and technology in the forestry. In stage 3, the contribution of the educational scientific and technological progress to the primary forestry industry turned from negative to positive, mainly because thanks to the further reform of rural taxation system and another reform in forest rights in 2008, the long-term ownership of peasants for forest lands were clarified, and ecological compensations for the forestry were furnished, boosting the scientific and technological popularization in the forestry.

Substituting the estimates in **Table 7** into equations (1) and (2), the modified tow-level CES functions of the periods of 1994-1997, 1998-2007, and 2008-2012 were obtained as shown in equations (12)-(17).

Two-level CES function of 1994-1998:

$$O_{it1} = \left(1.8E_{it}^{-0.23} - 0.8W_{it}^{-0.23}\right)^{4.35} \tag{12}$$

$$O_{it} = 2.72^{12.654}e^{0.058t}\left(1.16O_{it1}^{-0.39} - 0.16T_{it}^{-0.39}\right)^{0.71} \tag{13}$$

Two-level CES function of 1999-2007:

$$O_{it1} = \left(0.97E_{it}^{-0.02} + 0.03W_{it}^{-0.02}\right)^{50} \tag{14}$$

Table 8. The results of different regions estimation

Variable	Solve-for parameter	West Region		Northwest Region		*Northeast and Inner Mongolia Region*		South and Other Region	
		Estimated value	Z value	Estimated value	Z value	Estimated value	Z value	Estimated value	Z value
Constant term	z_0	4.355***	5.97	6.414***	16.53	9.954***	7.19	7.422***	16.91
X_{it}^1	z_1	0.010	0.62	0.036**	2.46	0.070**	2.13	0.007	0.42
X_{it}^2	z_2	-0.209	-0.91	1.216**	5.52	0.856*	1.95	0.631***	4.63
X_{it}^3	z_3	0.313***	2.98	-0.299	-1.59	-0.505	-1.36	0.127	1.23
X_{it}^4	z_4	0.656***	2.79	-0.129	-1.51	-0.104	-0.85	-0.011	-0.16
X_{it}^5	z_5	-0.050**	-2.22	0.085**	2.25	0.082	1.57	-0.016	-1.64
X_{it}^6	z_6	-0.060*	-1.81	0.026***	3.11	0.027	1.16	0.013	1.61
R^2		0.9726		0.9889		0.9555		0.9881	
Sample size		169		114		57		247	
Wald teat		174.68		843.91		25.90		637.76	

$$O_{it} = 2.72^{5.946} e^{-0.006t} \left(0.95 O_{it1}^{0.95} + 0.05 T_{it}^{0.95}\right)^{1.03} \tag{15}$$

Two-level CES function of 2008-2012:

$$O_{it1} = \left(0.95 E_{it}^{-0.12} + 0.05 W_{it}^{-0.12}\right)^{8.3} \tag{16}$$

$$O_{it} = 2.72^{7.707} e^{0.02t} \left(1.17 O_{it1}^{-0.43} - 0.17 T_{it}^{-0.43}\right)^{-1.43} \tag{17}$$

Regional Results and Discussion

China has a vast territory, with distinct differences in physic-geographical environment and economic & social development among different regions, which inevitably have a profound effect on the development of the primary forestry industry. As previously described by Wang Zhaojun in Regional division of forestry work and structural adjustment of regional forestry in China, the paper divides the forestry in China intro four regions, the West Region, the Northwest Region, the Northeast and Inner Mongolia Region and the South Region: the West Region includes Tibet, Qinghai, Yunnan, Guizhou, Sichuan, Chongqing, Gansu, Ningxia, and Guangxi; the Northwest Region includes Liaoning, Beijing, Tianjin, Hebei, Shanxi, Shaanxi, and Xinjiang; The Northeast and Inner Mongolia Region includes Heilongjiang, Jilin and Inner Mongolia, and the South Region include the others. The regionalism resulting in structural change of panel data, the paper makes use of panel-corrected standard errors (PCSE) for estimation of panel data model, to correct the effect of the change in data structure. **Table 8** shows the PCSE estimation results for the four regions.

The values of the parameters of the modified multi-factor two-level CES function (shown in **Table 9**) can be obtained by using the parameters estimated in **Table 8**, together with **Table 1**, followed by estimation of the modified two-level CES production function. **Table 9** shows that the speed of the educational scientific and technological progress in the primary forestry industry of the West Region, the Northwest Region, the Northeast and Inner Mongolia and the South Region was 2.43%, 5.4%, 8.4% and 8.33%, respectively. The average growth rate of the output value of the primary forestry industry of the West Region, the Northwest Region, the Northeast and Inner Mongolia and the South Region was calculated. Accordingly, according to equation (9), the contribution rate of the educational scientific and technological progress in the four regions was 41.15%, 12.96, 83.3% and 43.22, respectively. Based on the estimation results, the region of Northeast and Inner Mongolia was the region with the fastest educational scientific and technological progress and highest scientific and technological contribution, consistent with that fact that the region assumes the safeguard for ecological safety of the country, especially for the capital region, with the most national investment of funds and technology.

Table 9. The results of different areas estimation

Region											
West Region	Estimated parameter	z_0	z_1	z_2	z_3	z_4	z_5			z_6	
	Corresponding parameter	$\ln \lambda$	v	$n\chi_1\chi_3$	$n\chi_2\chi_3$	$n\chi_4$	$-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1$			$-\frac{1}{2}n\chi_3\chi_4\varphi$	
	Estimated value	4.355	0.010	-0.209	0.313	0.656	-0.050			-0.060	
	Single parameter	χ_1	χ_2	χ_3	χ_4	n	φ_1	φ	v_{it}	R_{it}	D_{it}
	Corresponding value	2.01	-1.01	0.14	0.86	0.76	0.47	1.34	1.0%	2.43%	41.15%
Northwest Region	Estimated parameter	z_0	z_1	z_2	z_3	z_4	z_5			z_6	
	Corresponding parameter	$\ln \lambda$	v	$n\chi_1\chi_3$	$n\chi_2\chi_3$	$n\chi_4$	$-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1$			$-\frac{1}{2}n\chi_3\chi_4\varphi$	
	Estimated value	6.414	0.036	1.216	-0.299	-0.129	0.085			0.026	
	Single parameter	χ_1	χ_2	χ_3	χ_4	n	φ_1	φ	v_{it}	R_{it}	D_{it}
	Estimated value	1.32	-0.32	1.16	-0.16	0.788	0.44	0.35	3.6%	8.33%	43.22%
Northeast and Inner Mongolia Region	Estimated parameter	z_0	z_1	z_2	z_3	z_4	z_5			z_6	
	Corresponding parameter	$\ln \lambda$	v	$n\chi_1\chi_3$	$n\chi_2\chi_3$	$n\chi_4$	$-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1$			$-\frac{1}{2}n\chi_3\chi_4\varphi$	
	Estimated value	9.954	0.070	0.856	-0.505	-0.104	0.082			0.027	
	Single parameter	χ_1	χ_2	χ_3	χ_4	n	φ_1	φ	v_{it}	R_{it}	D_{it}
	Corresponding value	2.44	-1.44	1.42	-0.42	0.247	0.13	0.37	7.0%	8.4%	83.3%
South and Other Region	Estimated parameter	z_0	z_1	z_2	z_3	z_4	z_5			z_6	
	Corresponding parameter	$\ln \lambda$	v	$n\chi_1\chi_3$	$n\chi_2\chi_3$	$n\chi_4$	$-\frac{1}{2}n\chi_1\chi_2\chi_3\varphi_1$			$-\frac{1}{2}n\chi_3\chi_4\varphi$	
	Estimated value	7.422	0.007	0.631	0.127	-0.011	-0.016			0.013	
	Single parameter	χ_1	χ_2	χ_3	χ_4	n	φ_1	φ	v_{it}	R_{it}	D_{it}
	Corresponding value	0.83	0.17	1.01	-0.01	0.747	0.30	3.43	0.7%	5.4%	12.96%

Substituting the estimates in **Table 9** into equations (1) and (2), the modified tow-level CES functions of the West Region, the Northwest Region, the Northeast and Inner Mongolia and the South Region are obtained as shown in Equations (18)-(25).

Two-level CES function of the West Region:

$$O_{it1} = \left(2.01E_{it}^{-0.47} - 1.01W_{it}^{-0.47}\right)^{2.11} \tag{18}$$

$$O_{it} = 2.72^{4.335}e^{0.01t}\left(0.14O_{it1}^{-1.34} + 0.86T_{it}^{-1.34}\right)^{-0.57} \tag{19}$$

Two-level CES function of the Northwest Region:

$$O_{it1} = \left(1.32E_{it}^{-0.44} - 0.32W_{it}^{-0.44}\right)^{2.27} \tag{20}$$

$$O_{it} = 2.72^{6.414} e^{0.036t} \left(1.16 O_{it1}^{-0.35} - 0.16 T_{it}^{-0.35}\right)^{-2.25} \quad (21)$$

Two-level CES function of the Northeast and Inner Mongolia:

$$O_{it1} = \left(2.44 E_{it}^{-0.13} - 1.44 W_{it}^{-0.13}\right)^{7.69} \quad (22)$$

$$O_{it} = 2.72^{9.954} e^{0.07t} \left(1.42 O_{it1}^{-0.37} - 0.42 T_{it}^{-0.37}\right)^{-0.66} \quad (23)$$

Two-level CES function of the South Region:

$$O_{it1} = \left(0.83 E_{it}^{-0.3} + 0.17 W_{it}^{-0.3}\right)^{3.33} \quad (24)$$

$$O_{it} = 2.72^{7.422} e^{0.007t} \left(1.01 O_{it1}^{-3.43} - 0.01 T_{it}^{-3.43}\right)^{-0.22} \quad (25)$$

In the four regions, the land input was negatively correlated with the output of the primary forestry industry in the West Region. For the West Region where the upper reaches of Yangtze River and the upper and middle reaches of the Yellow River dominate, most forests fell into the category of public welfare forests according to the Identification Measures for Ecological Public Welfare Forests of Key Level from State Forestry Bureau and Finance Ministry (Lin Ce Fa [2004] No.94), and were not included in the output value of the primary forestry industry: the more ecological public welfare forests, the less output value of the primary forestry industry. This is the reason for negative correlation. The situation in the other three regions was different from that in the West Region; in the principle of giving top priority to ecology, governments supported peasants to plant timber forests and economic forests to boost the development of rural economy, so the land input was positively correlated with the output of the primary forestry industry in these regions. In addition, it is necessary to note that the labor input was negatively correlated with the output in the Northwest Region and the Northeast and Inner Mongolia, and the capital input was negatively correlated with the output in the Northwest Region, the Northeast and Inner Mongolia, and the South Region. This is inconsistent with the theory. The main reason may be that the effect of the input factors is invisible in a short term due to the long production cycle of the forestry, and that there was a gradual decline of wood prices.

CONCLUSIONS

This paper makes an empirical analysis on the speed and contribution of educational scientific and technological progress in the primary forestry industry by developing a modified two-level CES production function and using the provincial panel data from 31 provinces between 1994 and 2012. The results show that first, in the overall development of the primary forestry industry, the speed and contribution of the educational scientific and technological progress were large, the speed being 2.8% and the contribution rate being 49.6%. Therefore, relying on educational scientific and technological progress will be an effective approach to develop the primary forestry industry; according to staged analysis, the contribution rate varied greatly in three stages, 1994-1998, 1999-2007 and 2008-2012: the educational scientific and technological progress contributed to the development of the primary forestry industry greatly, and an excessive contribution appeared due to the flood disaster in 1998, and the rapid industrialization and urbanization resulted in a negative contribution of the educational scientific and technological progress in the primary forestry industry, and the change in farming and forestry policies altered the effect of educational scientific and technological progress in the forestry. According to regional analysis, the speed and contribution of the educational scientific and technological progress in the primary forestry industry varied in different regions due to their diverse natural environment and economic circumstances, and consequently varied ability to assimilate educational scientific and technological progress, the contribution rate of the educational scientific and technological progress in the primary forestry industry in the Northeast and Inner Mongolia being much higher than in the other three regions. Second, the input of three production factors, labor, capital, and land contributed to the development of the primary forestry industry as a whole; however, in terms of stages and regions, the effect of the input of three factors varied: in stage 1, the land input was negatively correlated with the output of the primary forestry industry, so was the capital input in stages 2 and 3. The land input was negatively correlated with the output in the West Region, so was the labour input in the Northwest Region and the Northeast and Inner Mongolia, and the capital input in the Northwest Region, the Northeast and Inner Mongolia, and the South Region.

Based the analysis above, this paper brings forwards several recommends on promoting the primary forestry industry through educational scientific and technological progress: first, along with the development of the economy and society, the social and economic function shifts from the economic function dominated by timber production to the ecological protection function dominated by ecological service, so the industrial structure of the forestry needs important change, to strengthen the absolute status of the primary forestry industry in the forestry. Second, in the background of the accelerated industrialization and urbanization of China, decline in comparative income of the forestry operation and consequent decline in enthusiasm of peasants in the primary forestry industry, it is essential to increase the input in science and technology in the primary forestry industry to drive the development using educational scientific and technological progress. Third, it is important to strengthen policy support in the primary forestry industry and boost the contribution rate of educational scientific and technological progress to the development of the primary forestry industry relying on the social and economic policies. Forth, in the process of making the development policy and investment policy on the primary forestry industry, it shall not impose uniformity in all cases. On the contrary, the policy shall be different according to the different situations; and it is noticed that the comparative advantages of different regions with different social economic and natural resources shall be exerted.

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