Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

p-ISSN: 0972-6268 e-ISSN: 2395-3454	Vol. 17	No. 2	pp. 593-601	2018

Original Research Paper | Open Access

Technical Efficiency of the Industry Development and Influencing Factors of Carbon Sequestration Forestry: Evidence from China's Forest Resource Inventory

Weiwei Wang*(**), Ping Li*† and Junbiao Zhang***

*College of & Economics and Management, Huazhong Agricultural University, Wuhan 430070, China
**Institute of Technology of Agricultural Economy, Hubei Academy of Agricultural Sciences, Wuhan 430064, China
***School of Economics & Management, Hubei University of Technology, Wuhan 430068, China
†Corresponding author: Ping Li

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com

Received: 18-02-2018
Accepted: 15-04-2018

Key Words:
Carbon reduction
Carbon sequestration forestry
Ecological protection
Industrial development
Technical efficiency

ABSTRACT

The development of carbon sequestration forestry is internationally recognized as an important method for confronting climate change. This method plays a key role in implementing the carbon reduction commitment of China and is effective in realizing a green low carbon cycle development. The exploration of the leading role of carbon sequestration forestry development in environmental protection requires a systematic grasp of the development status of China's carbon sequestration forestry. The technical efficiency of China's carbon sequestration forestry development was calculated using all previous forest resource inventory data in China and a DEA-Tobit two-step method. Moreover, related influencing factors were discussed. Empirical results show that the technical efficiency of China's carbon sequestration forestry production in the evaluation years is at a high level. The promotion of carbon sequestration forestry development through policies and regulatory factors is increasing steadily, thereby also steadily improving the technical efficiency of carbon sequestration forestry production. A forestry output value, which represents industry development openness, of the tertiary industry and an average sunshine time, which represents natural endowment factors, exert a relatively limited influence on carbon sequestration forestry development. The conclusion provides the value of reference and decision support for a theoretical extension of forest resource protection, development and management, and improvement of a sustainable development system of carbon sequestration forestry.

INTRODUCTION

In recent years, ecological environment problems have attracted worldwide attention because of global climate change. The majority of countries (including developing countries, such as China) have demonstrated a clear willingness to develop a low-carbon economy and carbon sequestration forestry to national strategic heights, especially since the Paris Agreement was signed in 2016, to further slowdown the pace of climate change and complete their countries' commitments. Moreover, many countries increasingly and strongly appeal to seek a win-win cooperation mechanism for growth. The international community has adopted numerous mitigation measures since the 1990s given a deteriorating ecological environment caused by climate change. Thus, the focus of negotiators has slowly transferred from the previous energy, industrial system, and urban traffic architecture to the forestry, land use, and agricultural problems to address climate change in all kinds of negotiations. Among these methods, carbon sequestration forestry is considered a low-cost reduction measure for energy conservation, emission reduction, and ecological environment protection. Carbon sequestration forestry exhibits remarkable advantages over industrial emissions. This method demonstrates the characteristics of multiple effects, thereby attracting a steadily increasing attention of all parties. These advantages include favourable comprehensive benefits, low cost, ease of operation, adaptation to climate change, increase in ecosystem carbon reserves, effective reduction of carbon dioxide emissions, and biodiversity conservation. Carbon sequestration forestry is continuously exerting huge economic, social, and ecological benefits, especially because the Kyoto Protocol included this method into the provisions of the protocol's clean development mechanism (CDM). China is the fastest growing and most populous country of the world's forest resources. The ecological situation has improved markedly. Moreover, the production capacity of ecological products has steadily improved and can form approximately 500-600 million tons of carbon sequestration annually. This process largely contributes to addressing climate change and safeguarding the security of natural resources.

Carbon sequestration forestry has been utilized frequently in practical fields, such as sustainable protection and exploitation of natural resources, as an important option for protecting and restoring the ecological environment and actively mitigating and responding to climate change in developed and developing countries (Wu 2011, Alexandra 2013, Bussoni et al. 2010). Among these countries, Latin American countries led by Brazil and India have abundant natural resource endowments; moreover, they have achieved abundant results in forest carbon sequestration (Marcos 2006, Giles et al. 2006). The carbon sequestration project in China has caused a favourable momentum, although its development started relatively late in the country. The carbon sequestration pilot project and research in China have continued to increase since the country launched a global carbon sequestration project in 2001. China has implemented the world's first CDM forest carbon sequestrations and multiple forest carbon sequestration pilot projects. Currently, forest carbon sequestration projects in China achieve initial results. However, the size of the carbon sequestration forestry market, as an emerging field in China, is limited given many problems, such as nonpersistent carbon sequestrations, ineffective industry development mechanism of project development, hardly perfect technology support and talent training, inadequate financial support, and imperfect market mechanism and regulation, that emerged in such fields (Ye et al. 2006, Lu et al. 2013, Chen 2012). These malpractices gradually appeared in the forest carbon sequestration project implementation and seriously restricted the development of China's carbon sequestration forestry industry. The acceleration of the development of China's carbon sequestration forestry industry is a realistic and urgent task. Thus, Chinese mainland scholars have conducted several exploratory studies. In terms of market mechanism to build, He et al. (2007) considered that China must maximize the advantages, such as China's social and political stability, huge forest development space, and large forest solid carbon capacity growth potential, to promote the development of China's carbon sequestration trading market Li et al. (2010) and Wu (2010) affirmed the importance of building carbon sequestration trading market mechanism in the development process of the carbon sequestration forestry industry. In addition, Li et al. (2010) also considered that defining the property rights of forest carbon sequestration is the basis of establishing and perfecting the market mechanism. In terms of optimizing the policy system Lan et al. (2013) mentioned that carbon sequestration forestry trade should keep pace with the trend of green environmental protection; the process exerts the effect to continue resolving rural financial exclusion. Therefore, developing Chinese domestic carbon finance mechanism should be strengthened. Li et al. (2012) suggested that the carbon tax system should break the carbon tax burden of enterprises to participate in carbon sequestration afforestation and place carbon sequestration forestry before the carbon sequestration tax. Yan (2011) contended that determining the selection of a specific legal system is an urgent problem of the forest legal construction of China in addressing forest carbon sequestration. Chen et al. (2009) and Wu (2013) expounded on specific methods and main experiences of carbon sequestration forestry trade in developed countries, such as the United States and New Zealand. These authors presented their experiences in using market mechanisms to motivate emitters and complete the targets at a relatively low cost.

Existing literature has expounded on the importance of carbon sequestration forestry to ecological environment protection and global sustainable development. Developed and developing countries have conducted similar theoretical research on carbon sequestration forestry. However, the investigation was in the form of qualitative research and selected the breakthrough point of the ecological and economic significance of carbon sequestration forestry development, market mechanism construction of carbon sequestration forestry, and improvement of legal policy system. Part of the literature has investigated the estimation and value evaluation of forest carbon sequestration through natural science methods in quantitative research paradigm, which demonstrated strong interdisciplinary characteristics. However, limited literature discussed the carbon sequestration forestry for the natural resource industry and conducted quantitative research on its ecological environment protection and open-use effect and influence factors. The present study selects the carbon sequestration forestry industry as the research object and utilizes China's forest resource inventory data to perform quantitative analysis of technical efficiency and the influencing factors of carbon sequestration forestry industry development. Moreover, the present study is complementary to the theoretical literature of conservation, development, and utilization of ecological resources. Several conclusions obtained are of reference to a sustainable development practice of carbon sequestration forestry. The contents are presented as follows: introducing data and research methods, analysing the technical efficiency and influencing factors of the carbon sequestration forestry industry based on the DEA-Tobit model, and proposing the research conclusion.

MATERIALS AND METHODS

Data Sources and Indicator Selection

This study selects the time series data of China's provinces, cities, and autonomous regions (excluding Hong Kong, Macao, and Taiwan regions) in 1998-2013, and sample data come from the China Forestry Statistics Yearbook (1998-2014), the China Rural Statistical Yearbook (1999-2013), the Science and Technology of China Statistical Yearbook (1999-2013), the Previous Forest Resources Inventory Data (1973-2013), and the China Agricultural Yearbook (1999-2013). In addition, all data in currency are adjusted to the actual ratio of the base period in 1998 on the basis of the forestry output index in the total output index of China's agriculture, forestry, animal husbandry, and fishery to eliminate the influence of price fluctuation. In accordance with China's overall plan, the ninth forest resource inventory was launched in 2014 and an inventory task of seven provinces (municipalities), namely, Jilin, Zhejiang, Anhui, Hubei, Hunan, Shanxi, and Shanghai, were completed in the same year, together with the Jilin Forest Industry Group. The inventory task of seven provinces (regions), namely, Shanxi, Liaoning, Heilongjiang, Jiangsu, Guangxi, Ningxia, and Guizhou, was completed in 2015, together with the Longjiang Forest Industry Group and Daxinganling Forestry Group. A new round of forest resource inventory was completed in six provinces (regions, cities), namely, Beijing, Hebei, Jiangxi, Tibet, Gansu, Xinjiang, together with Xinjiang Production and Construction Corp. In February 2017, Sichuan Province also launched the forest resource inventory. The existing arrangement of the ninth forest resource inventory of China specified that the work will be completed in 2018. Thus, the recent data of forest resource inventory have not been fully disclosed (Table 1).

Input and output variables: This study uses a homogeneity of China's carbon sequestration forestry in 1998-2012 as the evaluation objects to satisfy application conditions of the DEA method. In addition, this study uses input and output variables of the carbon sequestration forestry industry development to build a DEA efficiency function and assumes all samples are faced with a homogeneous innovation environment or luck. The input and output variables of the technical efficiency of the carbon sequestration forestry industry development must generally select those closely related to carbon sequestration forestry production to satisfy the homogeneity requirements of the selected performance decision unit. Moreover, the following conditions must be achieved in an indicator setting and assignment. First, all decision-making units must use the same input and output factors, and each indicator value is positive. Second, the indicators involved must explain the core process of the carbon sequestration forestry development. Third, the dimensions of the different input and output indicators are inconsistent. On the basis of these findings, the main variables are defined as follows: (1) Output variable is expressed by measuring the value in a calendar year of the carbon sequestration forestry; (2) input variables contain land, human, material capital, and science and technology resources. Land resource input is represented by forest area. Human resource input is represented by the number of employees in the forestry system at the end of the year. Material capital input is represented by the total investment in forestry fixed assets completed since the beginning of the year, including annual forestry ecological construction and protection, forestry support and protection, forestry industry development, people's livelihood engineering, and other investments. Science and technology resource input is represented by the number of students in every school with forestry major per year.

Table 2 lists the input indicators selected, that is, forest area, number of employees in the forestry system at the end of the year, total investments in the forestry fixed assets completed since the beginning of the year, number of students in each school with forestry major per year; these indicators represent land resource, human resource, material capital, and science and technology resource inputs of the carbon sequestration forestry industry development. Output indicator is the carbon sequestration forestry value. An accurate estimation of the forest ecosystem carbon sequestration is the primary problem to be solved in the forest ecosystem carbon cycle study. Current measurements of the forest carbon sequestration mainly include volume, biomass, and biological listing methods based on volume and biomass methods. Different measurement methods demonstrate a significant difference in accounting results. Gu (2008) applied the method of plant molecular formula to measure the carbon content of different tree species. The result was used as parameter and dynamically predicted China's forest carbon sequestration function. The measurement method that this author used is relatively simple and has a theoretical basis. Thus, this author used this method to obtain forestry carbon sequestration value. Table 3 presents the specific value of each indicator.

Influencing factor selection: The study of the related factors that influence the production technical efficiency of carbon sequestration forestry should select the factors that cannot be controlled or changed in the short term.

The factors that influence production technical efficiency of carbon sequestration forestry generally include social and economic conditions, policy and institutional factors, and natural resource endowment. With limited sample size, it preliminarily selects four variables as the main factors that influence production technical efficiency carbon sequestration forestry (Tian 2013, Li 2011). First, economic and social condition indicators are selected. The production of the forestry tertiary industry represents the development level and openness of the forestry industry. Second, policy and institutional factor indicators are used. Fi-

Table 1: Basic situation of China's forest resource inventory data.

Number	Period	Volume of living trees/hundred million cubic meters	Forest area/hundred million hectares	Forest accumulation/ hundred million cubic meters	Forest cover rate/%
1	1973-1976	95.32	1.22	85.56	12.7
2	1977-1981	102.61	1.15	90.28	12
3	1984-1988	105.72	1.25	91.41	12.98
4	1989-1993	117.85	1.34	101.37	13.92
5	1994-1998	124.88	1.59	112.67	16.55
6	1999-2003	136.18	1.75	124.56	18.21
7	2004-2008	149.13	1.95	137.21	20.36
8	2009-2013	164.33	2.08	151.37	21.63

Date resource: China's forest resource inventory in 1973-2013, with eight forest resource inventories.

Table 2: Input and output variables of the technical efficiency of carbon sequestration forestry industry development.

Variable classification	Input variables				Output variables
Research variables	Land resource input	Human resource input	Material capital input	Science and technology resource input	Carbon sequestration output
Specific expression	Forest area	Number of employees in the forestry system at the end of the year	Total investments in the forestry fixed assets completed since the beginning of the year	Number of students in every school with forestry major per year	Forest carbon sequestration value
Dimension	Hundred million hectares	Person	10000 yuan	Person	Gt

Table 3: Specific situation of the input and output elements of the technology efficiency of the carbon sequestration forestry industry development.

Year	Forest area (hundred million hectares)	Number of employees in the forestry system at the end of the year (person)	Total investment in the forestry fixed assets completed since the beginning of the year (ten thousand yuan)	Number of students in each school with forestry major per year (person)	Forest carbon sequestration value		
					Carbon sequestration value (Gt)	Carbon sequestration intensity (mg/10000 yuan)	Carbon sequestration Density (Gt/ hundred million cubic meters)
1998	1.59	2114248	874648	129302	18.80	689.19	11.82
1999	1.75	2013378	902628.86	134804	18.93	672.44	10.82
2000	1.75	1816752	951374.75	147328	19.10	643.72	10.91
2001	1.75	1693766	944565.61	169661	19.27	654.13	11.01
2002	1.75	1591965	1011366.9	186705	19.44	616.31	11.11
2003	1.75	1508654	1082165.2	229036	19.58	580.14	11.19
2004	1.95	1465026	1103811	263126	19.72	572.83	10.11
2005	1.95	1424048	1139142.4	260337	19.82	557.88	10.16
2006	1.95	1394450	1202725.8	274436	19.94	531.58	10.23
2007	1.95	1374843	1285752.7	291028	20.04	499.75	10.28
2008	1.95	1325304	1389579.5	300499	20.15	464.95	10.33
2009	2.08	1316405	937164.34	332459	20.25	692.82	9.74
2010	2.08	1373069	1585985.2	487987	20.36	411.62	9.79
2011	2.08	1353961	1706444.4	514412	20.46	384.44	9.84
2012	2.08	1329057	1820432.9	523362	20.59	362.66	9.90

nancial and forestry fixed asset investment represents the macro forestry policy of the government, and its variable selection is represented by the state investment in forest fixed asset investment. A virtual variable of the system is mainly concerned with the influence of forest right system reform on production efficiency of carbon sequestration. The value before the forest change is 0, and the value after the forest change is 1. Third, natural resource endowment factor is adopted. The average sunshine time in China reflects the climate resources and other natural factors that influence the production technical efficiency of carbon sequestration forestry. This value uses the mean of the total value of the annual average rainfall of the major cities in China given the annual statistical range city number 31, 34, or 35.

Tables 3 and 4 list the assignment and mathematical statistics of the input and output indicators and related influencing factors of the production technical efficiency of carbon sequestration forestry. The tables present the following information. First, land resources, human resource, material capital, science and technology resource input, and forest carbon sequestration value exhibit a large difference in the process of carbon sequestration forestry development. Second, the process is affected by social and economic conditions, macro policy of the government, natural environmental factors, and random factors of the carbon sequestration forestry development. Third, the production of the forest tertiary industry, financial and forestry fixed asset investment, total investment in the forestry fixed assets completed at the beginning of the year, the number of students in each school with forestry major per year, and forest carbon sequestration value increase over time. Simultaneously, the number of employees in the forestry system at the end of the year, intensity of carbon sequestration, and density of carbon sequestration decline over time.

Research Model Construction

In the DEA method, the evaluation main body is aimed at reaching the optimal scale in imperfectly competitive markets, government policy, and fiscal constraints when all evaluation objects were the optimal state of the carbon sequestration forestry development, assuming that a constant return to scale (CRS) is desirable. Owing to this context, scholars have further proposed improving the DEA method of the CRS to solve the situation of a variable return to scale (VRS) in the decision-making unit, thereby leading to the wide application of the VRS. Owing to the lenient condition of the VRS, the model could measure the technical efficiency without influence from scale efficiency. The present study uses the VRS model to measure the annual technical efficiency of carbon sequestration for the optimal state forestry development to guarantee that the empirical result is scientific. In most studies, inputs, as the decision-making variables of an evaluation unit, have been easily controlled. Thus, scholars have selected the input-oriented model. However, the present study considers obtaining the maximum carbon sequestration forestry output under the given input and thus selects the output-oriented model.

$$\begin{cases} \underset{\theta,\lambda}{Min}\ \theta^{k} \\ s.t.\theta^{k} x_{n,k} \ge x_{n,k}\lambda_{k} \\ y_{m,k}\lambda_{k} \ge y_{m,k} \\ \lambda_{k} \ge 0\ (k = 1, 2, \ldots, 15) \\ \sum_{k=1}^{15} \lambda_{k} = 1 \end{cases} \quad ...(1)$$

In Formula (1), the total number of decision-making units (DMUs) is 15. Each DMU has *n* inputs and *m* outputs. Columns $x_{n,k}$ and $y_{m,k}$ correspond to the input and output of the *k*th evaluation year. In particular, input matrix $x_{n,k}$ for N×1 and output matrix $x_{n,k}$ for M×1 correspond to all the input and output data of *k* samples. λ_k represents the weighted coefficient of the *n*th input and *m*th output. θ_k represents the relative efficiency value of the *k*th DMU that belong to [0,1], and the value that is close to 1 indicates the high efficiency. For example, the innovation efficiency of the sample is the optimum when $\theta_k = 1$. Moreover $x \ge 0$, $y \ge 0$, $n = 4$ and $m = 1$.

A two-stage method is derived from the estimation of the relative performance on the basis of the DEA evaluation method to further demonstrate the influence factors and influence degree of technical efficiency of carbon sequestration development. The first stage is using the DEA method to estimate the annual efficiency value of the carbon sequestration forestry development. The second step is using the measured annual technology efficiency value as the dependent variable for performing a regression of various influencing factors. Then, this step judges the effect of various factors on the direction and degree of relative efficiency by using the coefficient of the independent variables. Parameter estimates may tend to zero using an ordinary least squares regression model because the efficiency index of the DEA method is limited to (0, 1). This study uses the Tobit regression model because the dependent variable is limited. The standard model is as follows:

$$\begin{aligned} & Y_i^* = \beta X_i + \varepsilon_i \\ & Y_i = Y_i^*, \quad if\ Y_i^* > 0 \\ & Y_i = 0, \quad if\ Y_i^* \le 0 \end{aligned} \quad ...(2)$$

In Formula (2), Y_i^* is the dependent variable vector, Y_i is the efficiency value vector, X_i is the independent variable vector. β is the correlation coefficient vector, $\varepsilon_i \sim N(0, \delta^2)$,

Table 4: Descriptive statistical analysis of independent variables.

Independent variable	Dimension	Minimum	Maximum	Average	Standard deviation
Production of forestry tertiary industry	10000 yuan	1085242	2258748.90	1483784.75	376097.69
Financial and forestry fixed asset investment	10000 yuan	374386	779221.56	511874.99	129745.91
Forestry reform	-	0	1	0.27	0.46
Average sunshine hours	Hours	1920.62	2087.98	1992.09	44.15

Table 5: Technical efficiency of China's carbon sequestration forestry development in 1998-2012.

Year	Carbon sequestration value				Carbon sequestration intensity				Carbon sequestration density			
	Technical efficiency	Pure technical efficiency	Scale efficiency	Note	Technical efficiency	Pure technical efficiency	Scale efficiency	Note	Technical efficiency	Pure technical efficiency	Scale efficiency	Note
1998	1	1	1	-	1	1	1	-	1	1	1	-
1999	1	1	1	-	0.997	1	0.997	irs	0.937	1	0.937	irs
2000	1	1	1	-	0.993	1	0.993	irs	0.987	1	0.987	irs
2001	1	1	1	-	1	1	1	-	1	1	1	-
2002	1	1	1	-	0.963	1	0.963	irs	1	1	1	-
2003	1	1	1	-	0.908	1	0.908	irs	1	1	1	-
2004	0.977	0.992	0.985	drs	0.851	0.857	0.993	irs	0.925	0.925	1	-
2005	1	1	1	-	0.848	1	0.848	irs	0.95	1	0.95	irs
2006	1	1	1	-	0.802	0.977	0.822	irs	0.968	0.993	0.974	irs
2007	0.991	0.998	0.992	drs	0.748	0.858	0.872	irs	0.975	0.976	1	-
2008	1	1	1	-	0.702	1	0.702	irs	1	1	1	-
2009	1	1	1	-	1	1	1	-	1	1	1	-
2010	0.967	0.993	0.974	drs	0.587	0.594	0.988	drs	0.915	0.928	0.986	drs
2011	0.981	0.996	0.985	drs	0.551	0.555	0.992	drs	0.932	0.94	0.992	drs
2012	1	1	1	-	0.522	0.523	0.997	drs	0.956	0.957	0.999	drs
Mean	0.994	0.999	0.996	-	0.832	0.891	0.938	-	0.97	0.981	0.988	-

and $y_i^* \sim N(0, \delta^2)$.

RESULTS AND DISCUSSION

Analysis of the technical efficiency of carbon sequestration forestry based on the DEA method: This study uses DEAP 2.1 software to measure the technical efficiency of carbon sequestration value, intensity, and density on the basis of the VRS model. The empirical results demonstrate that the average value of the technical efficiency of carbon sequestration forestry is 0.994, considering the management inefficiency, environment, and complex factors, such as random disturbance. The average values of the pure technical and scale efficiencies are 0.999 and 0.996, correspondingly. These findings suggest that technical efficiency only has a 0.6% improvement in the existing social and economic conditions, policy and institutional environment, and investment level. These findings are crucial to China's carbon sequestration forestry development in 2004, 2007, 2010, and 2014, which shows a decreasing trend. The average value of the technical efficiency of carbon sequestration strength is 0.832, whereas that of the pure technical efficiency is 0.891. Furthermore, the average value of scale efficiency is 0.938. Therefore, the technical efficiency of carbon sequestration intensity improved by 16.8%. The production of the carbon sequestration intensity exhibits an increasing trend in most years; this outcome is different from that of the carbon sequestration production situation. Simultaneously, the production of carbon sequestration intensity has reflected a decreasing trend in recent years, thereby attracting sufficient attention in 2010, 2011, and 2012. The average value of the technical efficiency of carbon sequestration density is 0.97, whereas that of the pure technical efficiency is 0.981; in addition, the average value of scale efficiency is 0.988. Therefore, the technical efficiency of the carbon sequestration density has improved by 3%. Similar to carbon sequestration intensity, the production of carbon sequestration density also exhibits a decreasing trend in 2010, 2011, and 2012 (Table 5).

Table 6 presents the technical efficiency distribution of the three kinds of carbon sequestration forestry production

Table 6: Technical efficiency distribution of carbon sequestration.

Technical efficiency of carbon sequestration	<0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
Number of samples	0	0	0	0	0	15
Rate (%)	0	0	0	0	0	100
Technical efficiency of carbon sequestration intensity	<0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
Number of samples	0	3	0	2	3	7
Rate (%)	0	20	0	13	20	47
Technical efficiency of carbon sequestration density	<0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
Number of samples	0	0	0	0	0	15
Rate (%)	0	0	0	0	0	100

Table 7: Pure technical efficiency distribution of carbon sequestration.

Pure technical efficiency of carbon sequestration	<0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
Number of samples	0	0	0	0	0	15
Rate (%)	0	0	0	0	0	100
Pure technical efficiency of carbon sequestration intensity	<0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
Number of samples	0	3	0	0	2	10
Rate (%)	0	20	0	0	13.3	66.7
Pure technical efficiency of carbon sequestration density	<0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
Number of samples	0	0	0	0	0	15
Rate (%)	0	0	0	0	0	100

by expounding the data in Table 5. In the 15 evaluation years, technical efficiency is in the (0.9, 1) interval. All evaluation years of the technical efficiency of carbon sequestration value and density are in the (0.9, 1) interval, but 80% of the evaluation years of technical efficiency intensity are more than 0.7, and 47% of the samples are in the (0.9, 1) interval.

Tables 7 and 8 present the pure technical and scale efficiency distributions of the three kinds of carbon sequestration forestry production, respectively, and the statistical results confirm that most evaluation years of the pure technical efficiency of carbon sequestration forestry are in the (0.9, 1) interval. All evaluation years of the pure technical efficiency of carbon sequestration value and density are in the (0.9, 1) interval. Moreover, 80% of the evaluation years of the pure technical efficiency of carbon sequestration intensity are also more than 0.8, and 66.7% of the samples are in the (0.9, 1) interval.

In terms of the scale efficiency of the samples, the efficiency of the carbon sequestration forestry development is favourable. Overall, most evaluation years of the pure technical efficiency of carbon sequestration forestry are in the (0.9, 1) interval. All evaluation years of the scale efficiency of carbon sequestration value and carbon sequestration density are in the (0.9, 1) interval. A total of 6.6% of the samples are less than 0.8, and 73.3% of the samples are in the (0.9, 1) interval.

Tobit regression analysis process: For further inspection of the direction and degree of economic and social conditions, policy and institutional factors, and effect of natural factors on the technical efficiency of carbon sequestration forestry production, this study uses three dimension values, which are measured in the first stage of the DEA method, of the technical efficiency of carbon sequestration forestry as the dependent variable. Then, social and economic conditions, policy and institutional factors, and natural factors are selected as the independent variables with 12 indicators. Finally, Tobit regression is conducted through EVIEWS7.2 package. The results are summarized in Table 9.

The regression results in Model 1 confirm that financial and forestry fixed asset investment, forestry reform, and average sunshine hours positively affect the technical efficiency. Based on the value or assignment of each variable, fiscal forestry investment, policy reform, and natural resource endowment positively correlate with the technical efficiency of the carbon sequestration forestry development. Two policy variables exhibit significant positive effects at the 5% and 10% levels. The production of the forestry tertiary industry demonstrates a significant negative effect on the technical efficiency of carbon sequestration forestry at a 10% level, but the effect coefficient is only 0.0086. The regression results in Model 2 confirm that financial and forestry fixed asset investment and forestry reform exert a significant positive effect on the technical efficiency of car-

Table 8: Scale efficiency distribution of carbon sequestration.

Scale efficiency of carbon sequestration	<0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
Number of samples	0	0	0	0	0	15
Rate (%)	0	0	0	0	0	100
Scale efficiency of carbon sequestration intensity	<0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
Number of samples	0	0	0	1	3	11
Rate (%)	0	0	0	6.6	20	73.3
Scale efficiency of carbon sequestration density	<0.5	0.5-0.6	0.6-0.7	0.7-0.8	0.8-0.9	0.9-1
Number of samples	0	0	0	0	0	15
Rate (%)	0	0	0	0	0	100

Table 9: Results of the Tobit regression.

Dependent variable	Model 1	Model 2	Model 3
Constant	0.9458^{***}(95.74)	1.874261^{***}(53.54)	1.6920^{***}(33.49)
Production of forestry tertiary industry	-0.0086^{*}(-1.92)	-0.0371^{***}(-24.74)	0.0192^{**}(-2.06)
Financial and forestry fixed asset investment	0.0249^{**}(-2.14)	0.1075^{***}(-9.26)	0.0557^{*}(-1.73)
Forestry reform	0.0010^{*}(-1.86)	0.0513^{**}(-2.90)	0.0180(-1.57)
Average sunshine hours	0.00003(-0.15)	-0.0002(0.93)	-0.00031(-0.40)

Note: The value of z-statistic is in parantheses, and the corresponding significance levels of *, ** and *** are 1%, 5% and 10%.

bon sequestration intensity at the 1% and 5% levels, respectively. The production of the forestry tertiary industry and average sunshine hours negatively affect the technical efficiency of carbon sequestration value. In addition, the production of the forestry tertiary industry is significantly negative, but the average sunshine hours are negligible. The regression results in Model 3 confirm that the production of the forestry tertiary industry, financial and forestry fixed asset investment, and forestry reform positively affect the technical efficiency of carbon sequestration density. Moreover, the carbon sequestration development openness degree and fiscal forest policy demonstrate significant positive effects at the 5% and 10% levels, correspondingly. The average sunshine hours can be negligible despite its confirmed negative effect.

In conclusion, the regression results of the three models include the consensus of opinions. Policy and institutional factors play a significantly positive role in the carbon sequestration forestry development. This process is the basic condition for improving the technical efficiency of carbon sequestration forestry production. Natural factors are in a subordinate position in the carbon sequestration forestry development, and its effect is relatively limited. Specifically, institutional variables, namely, financial and forestry fixed asset investment and forestry reform, positively affect the technical efficiency of carbon sequestration forestry production. The latter benefits from the full implementation of forestry reform and fiscal supporting policy of the Chinese government. The promotion of natural forest resource protection and sustainable development is consistent with the positive forest management that is implemented in Sweden (Leif et al. 2017).

The positive forest management can adjust and control composition and structure, promote the growth of forests, and increase forest growth account, carbon reserve, and other ecological service functions to stimulate a sustainable growth of carbon sequestration forestry. Overall, market elements represented by the production of the forestry tertiary industry, negatively affect the technical efficiency of the carbon sequestration forestry development. This finding is possibly due to the lack of maturity in the carbon sequestration market development in China. Moreover, this finding is ineffective for interest in distribution and participation degree of forestry practitioners. Thus, its positive effect on the technical efficiency of carbon sequestration forestry has not been discovered. In fact, forest management activities in the role of carbon market mechanism can not only improve the function of forests to protect and beautify the environment, but also generate profit by selling carbon sequestration. The latter is a specific performance in which the “green water Castle Peak is the mountain of gold and silver,” as advocated by the Chinese government.

Owing to the above mentioned perspective, exploiting the power of market mechanism and enhancing the carbon sequestration forestry resource protection and development policy have become a reality and an urgency to promote the technical efficiency of China’s carbon sequestration forestry development. Furthermore, natural elements represented by the average sunshine hours exert a negligible effect on the technical efficiency of carbon sequestration forestry. On the one hand, the effect coefficient is minimal. On the other hand, the regression coefficient of the three equations that correspond to the variables is nonsignificant. The result is different from the related research conducted by Tian et al. (2013); these researchers found that natural factors must be reckoned with the technical efficiency of carbon sequestration forestry; the latter must be incorporated in the related forestry input-output analysis.

CONCLUSION

The development of the carbon sequestration forestry industry has become an international commitment to protect ecological environment and stimulate carbon emission reduction. In addition, concrete measures to promote transformation and upgrade natural resources have reached a broad consensus in the field of practice. The present situation of the development of China's carbon sequestration forestry industry must be clarified considering the logical starting point of optimizing ecological resource protection, development, and utilization policy. In contrast to the past literature, which focused on describing the research paradigm qualitatively, this study uses the forest resource inventory data in China (1973-2013), along with other statistical data. This study also uses the DEA-Tobit two-step method to perform quantitative calculation and analysis of the technical efficiency of the development of China's carbon sequestration forestry industry. Related influencing factors are discussed on the basis of the perspective of natural forestry resource, development, and management. The conclusions are as follows: First, the technical efficiency of China's carbon sequestration forestry production has consistently progressed at a high level despite the relatively limited evaluation years of China's carbon sequestration market scale. The technical and scale efficiencies are robust, but the pure technical efficiency value of carbon sequestration forestry is relatively low at the overall level of (0.8, 1). Furthermore, the carbon sequestration forestry development has been evidently decreasing in recent years. Second, policy and institutional factors demonstrate a positive effect on improving the efficiency of the carbon sequestration forestry development; thereby attaining a steadily improving technical efficiency of the carbon sequestration forestry production. Third, average sunshine hours, as a natural resource, exert a limited effect on the technical efficiency of the carbon sequestration forestry development. Moreover, the development level and openness of the forestry industry, as represented by the production of the forest tertiary industry, negatively affect the technical efficiency of the carbon sequestration forestry development.

REFERENCES

Alexandra, M., Rodrigues, J. and Tiago D. 2013. International trade and the geographical separation between income and enabled carbon emissions. Ecological Economics, 89(5): 162-169.

Bussoni, A., Guitart, L. and Estraviz, R. 2010. Private valuation of carbon sequestration in forest plantations. Ecological Economics, 69(3): 451-458.

Chen, X.T., Li, N.Y. and Gao L. et al. 2009. Current situation and development trend of the carbon sequestration market in the United States. Forestry Economics, 7(3): 76-80.

Chen, Y. 2012. Legal system construction of forest carbon sequestration financial supervision. Journal of China's University of Political Science and Law, 5(1): 133-137.

Giles, A. and Haripriya, G. 2006. Accounting for India's forest wealth. Ecological Economics, 59(4): 462-476.

Gu, K.P., Zhang, K. and Zhang, L.X. 2008. Research on the measurement method of forest carbon sequestration. Journal of Nanjing Forestry University (Natural Science Edition), 5(1): 105-109.

He, Y., Zhang, X.Q. and Liu, Y.X. 2007. The status and potential of China's forest carbon sequestration trade market. Forestry Science, 7(2): 106-111.

Lan, H., Zhu, Y. and Mu, Z.S. 2013. Innovation model of solving rural financial exclusion: empirical analysis of guiding fund return to the countryside of forest carbon sequestration transaction. Economic Theory and Economic Management, 4(2): 43-50.

Leif, G., Sylvia, H. and Mattias, L. et al. 2017. Climate change effects of forestry and substitution of carbon-intensive materials and fossil fuels. Renewable and Sustainable Energy Reviews, 67(18): 612-624.

Li, C.H., Li, N. and Luo, H.Y. et al. 2011. Analysis and optimization of China's forestry production efficiency based on DEA method. Chinese Agricultural Bulletin, 19(6): 55-59.

Li, H.Y. and Lu, J. 2012. The design of forest carbon exchange and carbon tax system. China Population Resources and Environment, S1: 110-113.

Li, S.X. and Zhou, Z.G. 2010. Research on the operation mechanism of forest carbon sequestration market. Journal of Beijing Forestry University (Social Science Edition), 2(1): 88-93.

Lu, J., Zhang, Y. and Li, H.Y. 2013. International experience of forest carbon sequestration transaction. China's Population Resources and Environment, 23(12): 22-27.

Marcos, A.T., Marcus, L.M. and Carvalho, M.G. 2006. Assessment of land use and land use change and forestry (LULUCF) as CDM projects in Brazil. Ecological Economics, 60(1): 260-270.

Tian, J. and Yao, S.B. 2013. Measurement and analysis of technical efficiency of China's forestry production. China Population Resources and Environment, 11(4): 66-72.

Wu, N.L. 2011. An empirical study on developing forest carbon trade in Heilongjiang Province. International Trade Issues, 7(2): 116-123.

Wu, S.G. 2010. The prospect of CDM forest carbon sequestration market and trading strategy of carbon credit. Forestry Science, 11(3): 152-157.

Wu, X.L., Zeng, Y.Y. and Zhang, S.D. et al.2013. Policy design and implementation effect analysis of New Zealand forestry participating in the national carbon emission trading schem. Forestry Economics, 11(3): 37-45.

Yan, S.P. 2011. System selection of forest carbon sequestration legal protection under the perspective of climate change. Journal of China University of Geosciences (Social Science Edition), 3(1): 42-48.

Ye, S.M. and Zheng, X.X. 2006. The latest development and countermeasures of carbon sequestration forestry projects in China and abroad. Forestry Economics, 4(1): 64-68.