The heterogeneous effect of forest tenure security on forestry management efficiency of farmers for different forest management types

Received 14 January 2022
Revised 11 March 2022
Accepted 23 March 2022

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Abstract

Purpose – After the Collective Forest Tenure Reform (CFTR) in China, the enthusiasm of farmers for forestry management is stimulated. However, the forest tenure security varies among farmers, making the research conclusions of its impact on forestry management efficiency inconsistent. Based on the survey data of 1,627 households from the collective forest regions in 6 provinces of China in 2017, this paper not only discusses the differences of farmers' forestry management efficiency after the reform, but also further explores the heterogeneous impact of forest tenure security on forestry management efficiency in combination with different forest management types.

Design/methodology/approach – This study employed the stochastic frontier production function model to measure the forestry management efficiency of farmers. Then, Tobit models were used to discuss the influencing factors of farmers' forestry management efficiency.

Findings – The results demonstrate that the improvement of farmers' forest tenure security can effectively improve forestry management efficiency, but the effect is affected by forest management types. For farmers who manage economic forests and non-timber forests, safe tenure promotes the forestry management efficiency; while for those who manage ecological public welfare forests, tenure security plays an opposite role.

Originality/value – Therefore, satisfying farmers' differentiated demands for forest tenure according to forest management types to improve forest tenure security and further refining supporting policies of collective forestry reform is of great significance to improve the efficiency of farmers' forestry management in collective forest regions.

Keywords Forest tenure, Tenure security, Forestry management efficiency, SFA

Paper type Research paper

The authors are indebted to the anonymous reviewers and editors.

Funding: "Research on Institutional Obstacles and Institutional Innovation of Practicing Xi Jinping's theory of 'Two Mountains' with Chinese Characteristics in the New Era" (2019BLRD09) supported by Beijing Forestry University.

Conflicts of interest: The authors declare no conflict of interest.

Forestry Economics Review
Vol. 4 No. 1, 2022
pp. 37-55
Emerald Publishing Limited
2631-3030
DOI 10.1108/FER-01-2022-0001

1. Introduction

In 2003, the Collective Forest Tenure Refom (CFTR) was piloted in collective forest regions, which account for 59% of China's forestland. This is another major change in the management system of China's rural forestland after the policy of "Three-fixes" on forest in 1981. The adjustment of management right of forestland elements is of great significance to improve the internal production relationship of forestry, stimulate the enthusiasm of farmers in forestry production, alleviate the contradiction between ecological protection and farmers' interests and promote the sustainable development of forestry. In 2018, the National Forestry and Grassland Administration's opinion on further enlivening the management right of collective forest pointed out that in accordance with the idea that "Lucid waters and lush mountains are invaluable assets", the overall efficiency and output of forestland can be improved by designing the utilization mode, approach, intensity and industrial distribution of collective forest resources. *The 14th Five-year Plan for forestry development* in 2020 emphasizes in its principles the economical, intensive and efficient use of resources, and the overall improvement of ecological, economic and social benefits of forest. However, with the deepening of the CFTR, the efficiency of forestry management may be weakened by forestland fragmentation and extensive management of farmers. Due to the long forestry production cycle, low return rate, scale effect is becoming increasingly important. What is the efficiency of farmers' forestry management after the decentralization of forest tenure? What are the factors influencing the differences in efficiency? Is it possible to find the optimal efficient ways to manage forestland in collective forest regions? These are all questions that need to be studied if China is to improve forestry management efficiency.

A large number of empirical studies have been conducted by academics on the impact of the CFTR on farmers' forestry management, and the following views have been broadly formed. The first group of views believes that the confirmation of forest tenure to households has strengthened farmers' perception of forestl tenure security (Yi *et al.*, 2014) and stimulated the productive activity of farmers (Song *et al.*, 1997). Safe forest tenure promotes farmers to invest in forestland (Qin and Xu, 2013), thus transforming the advantages of forest resources into economic advantages, which plays an important role in promoting farmers' income growth, rural economic development and sufficient supply of forest products in collective forest regions (Shi and Wang, 2016).

Stable tenure has also accelerated the occurrence of land transfer, which in turn improves the productivity of forestland (Gao *et al.*, 2021), and the income-generating effect of the CFTR is sustainable (He *et al.*, 2021). The second point of view is that tenure arrangement in collective forest regions emphasizes the fairness of initial distribution of forestland resources, but fails to achieve the goal of improving efficiency, and it is highlighted by the fact that the contradiction between family decentralized management and scale management (Liu and Wang, 2009). The new round of CFTR has intensified the fragmentation and decentralization of forestland to some extent (Kong *et al.*, 2013; Liu *et al.*, 2015). After the reform, farmers' forestland management is extensive and the scale efficiency is not high, which leads to low comprehensive efficiency of forestland production (Li *et al.*, 2014). From the perspective of tenure types, independent tenure will have a significant negative impact on the efficiency of forestry management compared to joint tenure (Wang *et al.*, 2019). In addition, some scholars believe that although the reform has accomplished the task of clarifying property rights and realized tenure security, it has not fully realized tenure stability and the rights owned by farmers in the actual production and management are not as expected. So tenure security dosen't have a substantial effect on the efficiency of forestry management (Chen *et al.*, 2018).

The factors that affect the efficiency of forest management also include the characteristics of forestland, supporting policies and household characteristics. However, the discussion of

collective forest tenure has not been combined with forest management types. It is found that farmers who manage different forest types have different tenure demands through investigation, which provides ideas for the adjustment of tenure policies and further detailed research. The purpose of this study is to verify, through empirical analysis, the differences in the influence mechanism of forest tenure on forestry management efficiency in combination with different forest management types, and then to effectively improve the forestry management efficiency of farmers through precise policies, so that forestry can play a greater role in rural revitalization and rural ecological construction.

Therefore, based on the data from the Economic Research Center of The National Forestry and Grassland Administration on farmers in China's collective forest regions in 2017, this paper not only discusses the differences of farmers' forestry management efficiency after the CFTR, but also further explores the heterogeneous impact of different forest management types on forestry management efficiency. The second part of this paper discusses the influencing mechanism of farmers' forestry management efficiency, the third part measures and analyzes farmers' forestry management efficiency, the fourth part analyzes the influencing factors of farmers' forestry management efficiency and the fifth part puts forward targeted policy recommendations.

2. Study on the influence of farmers' forest tenure on forestry management efficiency

2.1 Literature review on farmers' forest tenure after the CFTR

In the early 1980s, China carried out the policy of "Three-fixes" on forestry in collective forest regions, which aimed at stabilizing the ownership of mountains and forests. This policy implemented the responsibility system of forestry production by delineating self-retained mountainous land for villagers through allocating the right to use forestland and ownership of trees to peasant households without shifting the ownership of forestland belonging to the collectives (Liu *et al.*, 2019). Forestland in collective forest regions began to change from collective management to family decentralized management in the form of "Sub-forest home", forming a pattern of fragmented division and scattered use. However, due to the instability of tenure and the failure to keep up with relevant supporting policies, a large amount of forest resource was destroyed in a short period of time.

In 2003, with the core content of "clarifying tenure, liberalizing management, reducing taxes and fees, and standardizing circulation", a new round of CFTR began in Fujian province. On the premise of ensuring that the ownership of forestland belongs to the collectives, the right to use forestland and the ownership as well as use of trees are transferred to families or other economic entities in various ways, such as equalization of mountain and forests or equalization of shares and profits, and bidding. Since then, the reform rapidly spread to other provinces. After 2008, the new round of CFTR has been carried out nationwide, and by the end of 2012, the main task of CFTR in all provinces and autonomous regions had been basically completed.

After the forestland is confirmed to the household, in order to further solve the problem of unclear property rights of forestland, undone implementation of production subjects, lagging production mechanism and unfair distribution of benefits, fully mobilize the enthusiasm of farmers in forestry production, activate the vitality of forestry production, the government has introduced a series of forestry supporting policies such as "forestry mortgage loan, forestry insurance, forestry cooperatives". Studies on forestry supporting policies mainly focus on forest tenure mortgage loans (Liao *et al.*, 2012), forestland circulation (Min *et al.*, 2017), forestry subsidies (Wang *et al.*, 2020), forestry insurance (Zhang and Gao, 2011), forestry cooperatives (Han *et al.*, 2018) and forestry technological services (Liao *et al.*, 2014a).

2.2 Study on the influence of farmers' forestry management efficiency

2.2.1 Research methods of forestry management efficiency. Most scholars have used parametric and non-parametric analysis methods in the measurement of forestry management efficiency. The stochastic frontier analysis (SFA) is widely used in parametric methods: Kehinde *et al.* (2010) used SFA to quantify the technical efficiency of sawmills and ordinary least square (OLS) regression analysis to estimate the determinants; Xiong *et al.* (2018) used SFA and panel data model to empirically analyze the factors influencing forestry production efficiency in northwest China; Chen *et al.* (2018) used SFA and Tobit model based on plot survey data to reveal the influencing factors of forestland management efficiency in collective forest areas; Jia *et al.* (2019) used SFA and maximum likelihood estimation (MLE) methods to study the impact of the quality of forestry hired labor on the technical efficiency of forestry management. Meanwhile, data envelopment analysis (DEA) is widely used in non-parametric methods: Tong and Wang (2011) conducted an empirical study on the production efficiency of China Jilin Forest Industry Group based on DEA and Malmquist index method, emphasizing the importance of technology and intensive management; Liao *et al.* (2014b) used the DEA-Tobit two-stage model to examine the factors influencing the management efficiency of farmers' economic forests in southern Jiangxi; Li *et al.* (2014) classified and evaluated the efficiency of production factors of different types of commercial forests based on a three-stage DEA model; Chen *et al.* (2020) conducted a spatiotemporal empirical study on the coordinated development of forestry management efficiency and forest ecological security with the help of Super-CCR model, coupling coordination model and spatial panel models; Ma and Gao (2021) used the DEA-Tobit method to measure the production efficiency of farmers and used the hierarchical linear model (HLM) to test the moderating effect of business model on non-agricultural employment and forestry production efficiency. In addition, a scholar used both DEA and SFA methods to correct the investment efficiency values of listed forestry companies (Guan *et al.*, 2019). Some scholars have also applied cost-benefit approach (Clinch, 2000) and case study approach (Li *et al.*, 2007) to conduct relevant studies. Forestry production is highly influenced by natural and other random factors, and SFA can better explain the causes of efficiency losses than DEA (Musaba and Bwacha, 2014), so there is a scientific basis for using SFA to measure the efficiency of forestry management.

2.2.2 Factors affecting farmers' forestry management efficiency. The factors affecting the efficiency of farmers' forestry management can be summarized in terms of production factors, forestland characteristics, management organization forms and householder's and family characteristics. (1) Production factors. Forestry capital input can effectively improve forestry output, but with a certain lag (Zhan *et al.*, 2016). Meanwhile, forestry is a typical labor-intensive industry, and the effectiveness of labor supply directly affects farmers' forestland decision-making behavior, which in turn affects forestland output efficiency (Liao *et al.*, 2018). (2) Forestland characteristics. After the CFTR, family management became the main mode of collective forestland management in China. The characteristics of decentralized and fragmented management make many scholars begin to pay attention to the relationship between forestland scale and input–output efficiency. And the research mainly focused on the number of forest blocks (Liao *et al.*, 2014b), forestland stand conditions (Xu *et al.*, 2014) and forestland scale (Tian and Shi, 2017), but the research conclusions are not consistent. (3) Management organization forms. Cooperative production through family forestry farms and cooperatives can improve the organization of forestry production and management, and can also overcome the shortcomings of family operation in terms of scale economy and inefficient factor utilization (Ke *et al.*, 2014), thus improving the efficiency of forestry management. (4) Householder's and family characteristics. Age (Tian and Jia, 2004), gender (Zhu *et al.*, 2018), education (Wang *et al.*, 2011) of the householder, whether the householder is a village

cadre (Ke and Chen, 2016) and family size (Huang *et al.*, 2019) will have impacts on forestry production and management behavior and even output efficiency; The degree of part-time farming (Zhai *et al.*, 2013) and the share of forestry income in household income (Xu *et al.*, 2015a) also have a significant impact on forestry management efficiency.

2.3 Influencing mechanism of farmers' forest tenure on forestry management efficiency

After the CFTR, clear forest tenure improved the enthusiasm of farmers in forestry production. As a result of the reform, the forestland managed by farmers involves many types. For example, there are ecological public welfare forests and commercial forests classified by function; timber forests, charcoal forests, shelter forests, special-use forests and economic forests classified by concrete purpose. In addition, it can be divided into timber management and non-timber management according to the management types. Among the various classifications above, different forest management types have different payback periods and rates of return, and farmers have different input motivation, resulting in significant differences in management efficiency. In general, forest management types with short payback periods or high return rates will be more efficient. For example, compared with the ecological public welfare forests with low ecological compensation benefits, the return rates of input in commercial forests are more significant, so farmers are more willing to invest and manage, which will effectively improve the management efficiency. Compared with timber forests, charcoal forests, shelter forests and special-use forests with longer operating cycles, economic forests have shorter investment return cycles and high rates of return, so it will generate higher management efficiency. Compared with timber production with longer rotation periods, the management of non-timber forests is more significantly profitable. The operation of non-timber forests provides a new idea for coordinating the contradiction between ecological protection and farmers' income. Farmers are naturally willing to invest more elements in non-timber forests, which will make it more efficient. These differential impact mechanisms will be further verified in the later empirical studies. In addition, it needs further proof whether the effect of tenure security will be more significant for forestland types that farmers are more positive. And the empirical analysis results will provide more targeted suggestions for further protection of forest tenure. Therefore, this study will take into account farmers' forest management types and explain the mechanism of forest tenure security on forestry management efficiency from a more subdivided perspective.

3. Measurement and analysis of farmers' forestry management efficiency

3.1 Data collection

This paper uses research data from China's monitoring project of the CFTR in 2017 to conduct an empirical analysis. In order to comprehensively understand the progress of CFTR, the National Forestry and Grass Administration conducted a tracking survey in 7 provinces including Yunnan, Jiangxi, Hunan, Gansu, Fujian, Liaoning and Shaanxi, with 10 counties randomly selected in each sample province, and 5 sample villages were selected separately in each sample county, and about 10 farm households were randomly selected in each village for a one-on-one questionnaire survey. The sample data included a total of 70 sample counties, 350 villages and 3,509 households in 2017. The percentage of timber forests with long production cycles in the full sample was only 3.676%. To ensure the completeness of information and to meet the data requirements for efficiency measurement, only the sample of farmers with both input and output data is retained, which can explain the scientific nature

of efficiency measurement to a certain extent. At this time, only 26 farmers were left in Gansu province, which was not included in the final data because of weak representativeness. Finally, the data of 1,627 households in 60 counties in Yunnan, Jiangxi, Hunan, Fujian, Liaoning and Shaanxi provinces were used.

The questionnaires were conducted face-to-face with farmers. The main contents of the survey include the process of family participation in the CFTR, structure of forest tenure, the status of forest resources, the input–output situation of forestland, forestry related supporting policies and the basic household characteristics of farmers and so on.

3.2 Efficiency measurement methods and indicators

3.2.1 Basic connotation. Efficiency refers to the ratio of input and output of management subject in operational activities, mainly including technical efficiency and allocation efficiency. The former refers to the ability to make optimal use of resources, in other words, to minimize input under given conditions of output, or to maximize output under given conditions of input factors; the latter is to achieve the optimum of inputs under certain conditions of factor prices (Xu *et al.*, 2015b). Forestry management efficiency indicates whether all kinds of production factors have reached the optimal allocation in the process of forestry production. It reflects the realization degree of forest resource value (Shi and Zhang, 2012). When the efficiency value equals 1, it means that the forestry management efficiency has achieved the optimal state.

3.2.2 Measurement method and index selection. The SFA is a typical representative of parametric estimation method to efficiency evaluation, which needs to determine the specific form of production frontier. Compared with non-parametric estimation, its advantages are shown by considering the influence of random factors on output, more suitable for large sample calculation, and more stable results without the influence of outliers (Li and Fan, 2009). For cross-sectional data, SFA can be expressed as follows:

$$Y_i = f(x_i, \beta_i)\exp(v_i - u_i) \tag{1}$$

$$\mathrm{TE}_i = \exp(-u_i) \tag{2}$$

In the above equation, Y_i and x_i represent the output and input of the ith decision-making unit (DMU) respectively, β is the model parameter, and the compound disturbance term is a composite structure. v_i is the random factor affecting output, which is assumed to obey independent normal distribution, namely $v_i \sim N(0, \sigma_v^2)$; u_i represents the error caused by technical inefficiency, which is assumed to be a half-normal random variable with independent identical distribution, namely $u_i \sim N^+(0, \sigma_u^2)$. TE_i is technical efficiency, which ranges from 0 to 1, and it measures the relative difference between the output of the ith DMU and the output of a fully efficient DMU with the same inputs, that is, the ratio of actual output expectation to production frontier expectation.

In the process of efficiency measurement, scholars are basically consistent in selecting input and output indicators for forestry production and operation. Capital, labor and forestland area are usually selected as input indicators, while forestland output value is selected as an output indicator (Xu *et al.*, 2015a). Combined with the actual situation and data availability, this paper finally selected capital input, labor input and forestland area as input indicators and selected forestry economic benefit as an output indicator. The descriptions of forestry input and output indicators are shown in Table 1.

The C-D production function is selected as the model of the stochastic frontier production function and it is constructed as follows:

$$\ln Y_i = \beta_0 + \beta_1 \ln K_i + \beta_2 \ln L_i + \beta_3 \ln A_i + v_i + u_i \tag{3}$$

$$TE_i = \exp(-u_i) \tag{4}$$

In the equation above, Y_i is the total income of forestry production (yuan), K_i, L_i and A_i denote the capital input (yuan), labor input (day) and forestland area (mu) of the ith decision unit, respectively; β_0, β_1, β_2 and β_3 are parameters to be estimated; TE_i is the efficiency of forestry management. The main advantages of choosing C-D function are its simple form and direct economic meaning of parameters, β_1, β_2 and β_3 denote the output elasticity of capital, labor and land, respectively.

3.2.3 Parameter estimation results. Frontier 4.1 was used to estimate the parameters (Table 2), where the variation rate γ was used to determine whether SFA passed the test. The expression is as follows:

$$\gamma = \frac{\sigma_u^2}{\sigma_v^2 + \sigma_u^2} \tag{5}$$

In formula (5), σ_u^2 and σ_v^2 are the variance of inefficient terms u and v; The variation rate γ ranges from 0 to 1, and the approximation to 1 means that the stochastic frontier production function is reasonable.

The result shows that the value of γ is 0.838 and is significant at 1% level, which indicates that there is indeed inefficiency in farmers' forestry management. The compound error term of 83.8% comes from technical inefficiency and 16.2% from the disturbance of random factors, which indicates that the stochastic production function used in the model is valid.

3.3 Descriptive statistics of farmers' forestry management efficiency

3.3.1 The overall forestry management efficiency of farmers in collective forest regions is at a low level. By measuring the forestry management efficiency of 1,627 households, the overall efficiency values were divided into 4 groups according to the 25th percentile, as shown in Table 3.

Overall, most of the farmers' forestry management are inefficient. The average value of farmers' forestry management efficiency is only 0.287 which has a large gap with the effective efficiency value of 1 and still has much room for improvement.

3.3.2 Significant differences exist in the efficiency of farmers' forestry management across regions. The average level of forestry management efficiency of farmers in Fujian province is the highest, followed by Jiangxi, Yunnan, Liaoning and Shaanxi, and Hunan is the lowest (see Table 4). Fujian province has the highest forest coverage rate and has taken the lead in implementing the CFTR and comprehensive supporting reforms, which has enhanced the

The index type	Level indicators	The secondary indicators (unit)	Mean	Median	Standard error
Output indicator	Economic benefit	Total forestry output value (yuan)	18200.085	2297.860	84689.480
Input indicators	Capital	Forestry operational expenditure (yuan)	17948.851	4,800	85000.980
	Labor	Self-employment and employment (day)	132.299	36	620.651
	Forestland	Forestland area (mu)	131.216	41	413.881

Source(s): Monitoring Project of China's Collective Forest Tenure Reform in 2017, Economic Research Center, the National Forestry and Grassland Administration, the same below

Table 1. Input–output indicators of household forestry production

vitality of forestry development and significantly improved the efficiency of farmers' forestry production and management. Jiangxi province, second only to Fujian in terms of forest coverage, has seen an increase in forestry inputs and improved output efficiency in the background of the CFTR; Yunnan province has a vast forested area, sufficient water and heat, good quality forest stands and high forestry management efficiency among farmers; Liaoning and Shaanxi have low forestry management efficiency mainly due to their faint advantages in resource endowment and secondly due to diseconomies of scale. The low level of forestry management efficiency in Hunan province is related to the type of main source of income of farmers. More than 60% of sample farmers in Hunan province go out to work for a living, while less than 5% of farmers take forestry income as their main source of income (According to farmer's answer to the question: "whether the main source of income of the family is forestry production" in the questionnaire.) and they are not very enthusiastic about forestry production. In empirical research, "whether forestry is the main source of income" will be added for control to test the impact of the importance of forestry income on forestry management efficiency.

3.3.3 There are significant differences in efficiency of forest management types. In general, the efficiency of farmers' forestry management is closely related to the types of forest

Table 2. Parameter estimation results of C-D stochastic frontier production function

Parameter to be estimated	Estimate of parameter	Standard error	T statistic
Constant term	2.585***	0.382	6.767
ln(Capital)	0.661***	0.065	10.123
ln(Labor)	0.104	0.067	1.551
ln (Forestland)	0.285***	0.033	8.570
σ^2	7.142***	0.477	14.961
γ	0.838***	0.031	26.764
Likelihood function value		−3250.282	
Likelihood ratio tests one side value		44.427	
Sample size		1,627	

Note(s): ***, ** and * are significant at 1%, 5% and 10% levels respectively

Table 3. Forestry management efficiency of farmers

Efficiency interval	Mean	Median	Sample size	Percentage (%)
$0.001 \leq te < 0.108$	0.051	0.049	406	24.954
$0.108 \leq te < 0.278$	0.191	0.188	407	25.015
$0.278 \leq te < 0.443$	0.366	0.366	407	25.015
$0.443 \leq te \leq 1$	0.748	0.540	407	25.015
Total	0.287	0.278	1,627	100

Table 4. Efficiency of farmers' forestry management in sample provinces

Province	Mean	Median	Min	Max	Sample size
Yunnan	0.309	0.309	0.012	0.748	208
Jiangxi	0.350	0.366	0.019	0.705	224
Hunan	0.183	0.117	0.006	0.694	283
Fujian	0.359	0.415	0.001	0.739	331
Liaoning	0.277	0.267	0.002	0.730	253
Shaanxi	0.255	0.241	0.004	0.639	328
Total	0.287	0.278	0.001	0.748	1,627

(see Table 5). The highest average efficiency of forests are economic forests, which have short return on investment cycles, more flexible operation forms and more stable outputs. The efficiency of timber forests is lower than that of economic forests, which may be related to the longer return on investment periods. The average efficiency of non-timber forests is higher than the average of population. The development of non-timber forests can make full use of land resources and shady space, combine with breeding, collection and other activities. It can realize the transformation from simple utilization of forest resources to combined utilization of forest resources and forestland resources and finally reach the goal of "profits in the near term and forests in the long term". By shortening management cycles and bringing farmers higher economic returns, farmers' enthusiasm for non-timber forests production is stimulated and forestry management efficiency is improved. The efficiency of farmers who manage the ecological public welfare forests is the lowest. The main forestry income of these farmers is the ecological public welfare forest compensation. Due to the implementation of protective policies, logging is strictly prohibited, and farmers cannot obtain forestry income through market behaviors, which highlight the contradiction between forestry inputs and outputs, resulting in low efficiency of forestry management. According to the frequency distribution characteristics of forest management types, "Management in economic forests", "Management in non-timber forests" and "Management in ecological public welfare forests" are finally selected as dummy variables and crossed with the indicator of tenure security to further analyze the influence of forest tenure on forestry management efficiency.

4. Influencing factors of farmers' forestry management efficiency

4.1 Empirical model and variable selection

Since the efficiency values determined by SFA are restricted to between 0 and 1, using OLS for regression will lead to the situation that parameters exceed the range. Tobit model was used for the analysis based on existing studies. The specific model setting is as follows:

$$\mathrm{Te}_i = \beta_0 + \beta_1 \mathrm{Tenure}_i + \beta_2 \mathrm{Tenure}_i * \mathrm{FMT}_i + \sum_1^n \lambda_i \mathrm{CV}_i + \varepsilon_i \quad (6)$$

In the formula, Te_i represents the efficiency of farmers' forestry management. The key variable Tenure_i is an indicator of forest tenure security, considering four indicators: "whether there is a forest certificate," "whether there is forest tenure mortgage loan," "whether there is forestland circulation" and "whether there is logging." Specifically, forest certificate is an important indicator of tenure security, and only when forestland is registered and legally protected can the certainty of forest tenure be guaranteed (Brasselle *et al.*, 2002), and it means formal, legal security of tenure; forest tenure mortgage loan represents the

Provinces	Timber forests	Economic forests	Non-timber forests	Ecological public welfare forests
Yunnan	0.494 (19)	0.373 (87)	0.369 (42)	0.255 (98)
Jiangxi	0.457 (11)	0.350 (24)	0.422 (30)	0.335 (109)
Hunan	0.405 (8)	0.427 (8)	0.276 (13)	0.168 (241)
Fujian	0.490 (13)	0.492 (118)	0.413 (34)	0.292 (177)
Liaoning	0.346 (71)	0.403 (65)	0.343 (41)	0.248 (176)
Shaanxi	0.639 (1)	0.335 (58)	0.359 (21)	0.253 (251)
Total	0.400 (123)	0.411 (360)	0.372 (181)	0.248 (1,052)

Note(s): Some farmers are engaged in part-time employment

Table 5.
Average efficiency and frequency of different forest management types (household)

mortgage and transaction rights in the land property bundle (Sun and Xu, 2011); forestland circulation reflects the autonomy of farmers' forestland management after the CFTR (Cao *et al.*, 2014); timber harvesting right is a key institutional variable for forest tenure security (He *et al.*, 2014). These indicators reflect the realization of farmers' control power of forestland at the ground-truth level, including right of use, right of disposal and right of profit, as the main body of forestry production and management. Then Tenure_i is obtained by assigning and arithmetic averaging the plot area, and it is expressed as follows:

$$\text{Tenure}_i = \frac{\sum_1^{12}(\text{plot}_i * \text{ifce}_i) + \sum_1^{12}(\text{plot}_i * \text{ifml}_i) + \sum_1^{12}(\text{plot}_i * \text{ifci}_i) + \sum_1^{12}(\text{plot}_i * \text{iflo}_i)}{4 * \sum_1^{12}\text{plot}_i} \tag{7}$$

In equation (7), plot_i is the area of the ith forestland managed by peasant household; ifce_i represents whether the ith forestland has a certificate; ifml_i represents whether the ith forestland has forest tenure mortgage loan; iffc_i represents whether there is forestland circulation for the ith forestland; iflo_i represents whether there is logging in the ith forestland. The value range of tenure security indicator is between 0 and 1, and when Tenure_i becomes larger, it means that the degree of security of forest tenure becomes higher.

FMT_i is the forest management types of farmers, including "Management in economic forests," "Management in non-timber forests," and "Management in ecological public welfare forests"; CV_i $(i = 1, 2, \ldots, n)$ are control variables. β_0 is the constant term, β_1, β_2 are the parameters to be estimated and ε_i is the random disturbance term.

The control variables include forestry supporting policies, production factors and family characteristics. Detailed description and data description are as follows (Table 6):

(1) Forestry supporting policies. i) Forestry subsidies: expressed by forestry subsidies per mu, can promote farmers' enthusiasm in forestry production; ii) Participation in forestry cooperatives: cooperative operation can optimize the allocation of factors, improve the level of specialization and promote forestry management efficiency; iii) Adoption of forestry technological services: forestry technology training will improve farmers' forestry management skills and methods and ultimately improve the efficiency of forestry management.

(2) Production factors. i) Capital refers to total household forestry expenditure, which includes seedlings, fertilizer, machinery, animal power and so on. It is an indispensable mean of production for developing forestry management activities. ii) Labor refers to the number of household labor that plays a decisive role in forestry production. Forestry production has a weak quality and a long production cycle. The availability of sufficient capital and labor will work better with the land factor to produce higher efficiency.

(3) Family characteristics. i) Gender of householder: in forestry production, the male has labor efficiency superiority compared with the female in terms of physical ability. ii) Age of householder: The older the householder is, the more experienced in forestry production. But the ability of acquiring new technology and information is weak, which is not conducive to the improvement of forestry production efficiency. iii) Education level of householder: householder with high education can grasp advanced ideas and management methods, then promote the efficiency. iv) Householder is a village cadre: village cadre is often a capable person in the village and can quickly accumulate social capital and policy information, which is conducive to forestry production and management. v) Family size: sufficient family labor force is a guarantee to improve the efficiency of forestry management. vi) Forestry is the main source of income: the main income source represents the characteristics of

Variable type	Variable name	Variable interpretation	Mean	Standard deviation	Min	Max	Influence direction
Explanatory variable							
Forestry management efficiency	Te	By calculation	0.287	0.191	0.001	0.748	
Key explanatory variable							
Characteristics of forestland	Tenure	Calculated by weighting	0.277	0.084	0	0.759	+
Forest management types							
	Management in economic forests	1 = yes, 0 = otherwise	0.221	0.415	0	1	+
	Management in non-timber forests	1 = yes, 0 = otherwise	0.111	0.315	0	1	+
	Management in ecological public welfare forests	1 = yes, 0 = otherwise	0.647	0.478	0	1	−
Forestry supporting policies							
	Forestry subsidies	Ten- thousand-yuan per mu	0.003	0.015	0	0.323	+
	Participation in forestry cooperatives	1 = yes, 0 = otherwise	0.086	0.281	0	1	+
	Adoption of forestry technological services	1 = yes, 0 = otherwise	0.368	0.482	0	1	+
Production factors							
	Total household forestry expenditure	Ten- thousand-yuan	1.795	8.500	0.010	277.500	+
	Number of household labor	Person	2.778	1.330	0	9	+
Family characteristics							
	Gender of householder	1 = male, 0 = female	0.933	0.250	0	1	+
	Age of householder	year	55.853	10.492	22	88	−
	Education level of householder	1 = primary and below, 2 = middle school, 3 = high school, 4 = university or above	1.821	0.769	1	4	+
	Householder is a village cadre	1 = yes, 0 = otherwise	0.281	0.450	0	1	+
	Family size	Person	4.724	1.903	1	14	+
	Forestry is the main source of income	1 = yes, 0 = otherwise	0.147	0.354	0	1	+

Table 6.
Definitions and descriptive statistics of variables

household's livelihood, and farmer who takes forestry as the main income source will tilt production factors to improve forestry yield.

4.2 Results

Farmers' forestry management efficiency is the explanatory variable, and forest tenure security is the key explanatory variable. The indicator "forest tenure security" is multiplied by different forest management types to test the previous hypothesis (see Table 7).

4.2.1 Impact of tenure security on forestry management efficiency. Forest tenure security has a significant positive impact on the efficiency of forestry management. The issuance of certificates gives farmers clear and legally guaranteed bundle of rights. The forest tenure mortgage loan, forestland circulation and the timber logging reflect farmers' disposal and profit right of forestland resources from the fact level. The full realization of the forest tenure security leads to more forestland rights actually owned by farmers. The degree of forest tenure security becomes higher, and farmers are motivated to manage forestland, which eventually leads to the improvement of forestry management efficiency.

For farmers who manage economic forests, the positive effect of tenure security on forestry management efficiency has been verified for many times. With the improvement of tenure security, the efficiency of forestry management is also increasing. The initial stage of managing economic forests requires a large amount of capital, and secure tenure will increase the intrinsic enthusiasm of farmers in forest production, increase forestry inputs and realize the increase of income, thus driving the improvement of efficiency.

For farmers who manage non-timber forests, the higher the forest tenure security is, the better the efficiency of forestry management is. In multiple regression models, the positive effect of tenure security on forestry management efficiency is significant at the level of 1%. Secure tenure contributes significantly to efficiency growth and facilitate farmers to increase their income from engaging in forestry production and operation.

For farmers who manage ecological public welfare forests, the improvement of tenure security will restrain forestry management efficiency, which has been verified in models. At present, ecological public welfare forests are strictly prohibited from logging, but the subsidy standard is not perfect and flexible. So there is a far gap between the benefits of timber harvesting and subsidy income. The strict restriction of revenue right leads to low efficiency in forestry management.

4.2.2 Influence of control variables on forestry management efficiency. The positive effect of forestry subsidies on forestry management efficiency has been repeatedly verified, and it is significant at the level of 1% in models. In the process of forestry production, policy subsidies are beneficial to increase farmers' motivation in forestry production and improve the efficiency.

Participation in forestry cooperatives is an effective mean for farmers to improve forestry management efficiency. It makes it possible to improve market competitiveness and promote the improvement of farmers' forestry management efficiency by integrating resources and optimizing forestry production factors.

The age of householder has a significant negative effect on the efficiency of forestry production and management. It indicates that the limitation of physical and learning ability will affect the efficiency of forestry management as the age of householder increases.

The householder serving as the village cadre has certain positive influence on forestry management efficiency. There will be some advantages for a village cadre to have more social capital and channels to obtain forest management rights.

When forestry income is the main source of family income, the efficiency of forestry management of farmers is significantly higher than that of farmers who regard other income as the main source of livelihood. This means that the greater the importance of forestry in families' livelihood, the greater the incentive for farmers' forestry production.

Table 7.
Regression results

Variable type	Variable name	Te	Te	Te	Te	Te
Characteristics of forestland tenure	Tenure	0.2750*** (0.0626)	0.2780*** (0.0620)	0.2780*** (0.0621)	0.2330*** (0.0617)	0.0777 (0.0676)
	Tenure * Management in economic forests	0.4700*** (0.0469)	0.4570*** (0.0472)	0.4570*** (0.0473)	0.4140*** (0.0472)	0.4010*** (0.0465)
	Tenure * Management in non-timber forests	0.3710*** (0.0467)	0.3610*** (0.0475)	0.3630*** (0.0477)	0.3530*** (0.0481)	0.3340*** (0.0475)
	Tenure * Management in ecological public welfare forests	−0.1980*** (0.0347)	−0.1990*** (0.0346)	−0.2000*** (0.0346)	−0.1860*** (0.0345)	−0.1460*** (0.0339)
Forestry supporting policies	Forestry subsidies		1.1660*** (0.2780)	1.1660*** (0.2760)	1.2270*** (0.2790)	1.1920*** (0.3200)
	Participation in forestry cooperatives		0.0359** (0.0148)	0.0362** (0.0148)	0.0270* (0.0148)	0.0210 (0.0150)
	Adoption of forestry technological services		0.0131 (0.0091)	0.0132 (0.0091)	0.0074 (0.0090)	0.0082 (0.0095)
Production factors	Total household forestry expenditure			−0.0006 (0.0007)	−0.0008 (0.0008)	−0.0010 (0.0008)
	Number of household labor			0.0035 (0.0034)	0.0060 (0.0043)	0.0025 (0.0043)
Family characteristics	Gender of householder				0.0243 (0.0173)	0.0177 (0.0172)
	Age of householder				−0.0011** (0.0004)	−0.0009** (0.0004)
	Education level of householder				−0.0027 (0.0060)	−0.0049 (0.0060)
	Householder is a village cadre				0.0168* (0.0102)	0.0033 (0.0101)
	Family size				−0.0035 (0.0031)	−0.0016 (0.0031)
	Forestry is the main source of income				0.0636*** (0.0130)	0.0550*** (0.0127)
Region dummy variables		No	No	No	No	Yes
Constant		0.2060*** (0.0195)	0.1950*** (0.0194)	0.1870*** (0.0213)	0.2420*** (0.0382)	0.2730*** (0.0414)
Observations		1,627	1,627	1,627	1,627	1,627

Note(s): ***, ** and * are significant at the level of 1%, 5% and 10% respectively. Standard error is indicated in brackets

Among other control variables, the adoption of forestry technological services, total household forestry expenditure, the number of household labor and householder's personal characteristics such as gender and education level as well as family size all show no significant correlation with forestry management efficiency.

5. Conclusions and recommendations

5.1 Conclusions

5.1.1 The efficiency of farmers' forest management in collective forest regions is at low level. Although there are some differences in the efficiency of farmers' forestry management among the sample provinces, in general, they have not achieved efficient production, with an average efficiency value of 0.287, which is still a long way from achieving the relative efficiency value of "1". It indicates that most of the farmers in collective forest regions use relatively crude ways in forestry production and management, and the utilization of various resources does not reach the optimal allocation, and the input and output do not achieve the best effect.

5.1.2 Forest tenure security has a significant effect on forestry management efficiency. Secure forest tenure has a significant positive effect on the improvement of forestry management efficiency. During the implementation of the new round of CFTR, farmers have been given more property rights, and their rights to occupy, use, dominate and dispose forestland have been further guaranteed. The definition of forest tenure ultimately affects the efficiency level of forestry production by stimulating investment and rational allocation of factors. Safe forest tenure has increased the enthusiasm of farmers who engage in forestry production, and it highlights the contribution to the efficiency of forestry management. After controlling the difference of provinces, the positive effect of tenure security on the efficiency of forestry management is not significant. It is probably due to the differences in the understanding and implementation of policies in different provinces and the existence of problems such as property rights disputes, which make the bundle of forest tenure obtained by farmers not as expected. At the same time, traditional ways of forestry production and management have not changed substantially, offsetting the positive incentive effect of tenure security.

5.1.3 The influence of forest tenure security on efficiency varies according to forest management types. Forest types managed by farmers influenced the degree and direction of the effect of tenure security on management efficiency. Forest tenure security has a significant positive effect on forestry management efficiency for farmers who manage economic forests and non-timber forests. Both of these forms are flexible and can achieve economic benefits in short periods. Compared with farmers engaged in non-timber forests production, those who manage economic forests is more sensitive to tenure security. As for farmers operating ecological public welfare forests, China implements ecological public welfare forest compensation policy to alleviate the contradiction between ecological public welfare forest protection and farmers' livelihoods, which restricts farmers' independent management activities and adversely affects farmers' forestry production activities. Although ecological public welfare forest compensation can compensate farmers' losses to a certain extent, it is far from the opportunity cost of managing forestland. In fact, farmers are not highly satisfied with the compensation policy, which finally has a negative impact on forestry management efficiency. Therefore, it shows that the effect of forest tenure security on forestry management efficiency may be influenced by forest management types, investment return cycles and so on.

5.2 Suggestions

5.2.1 Fully guarantee forest tenure, reduce the restriction and make clear tenure promote the efficiency of forestry management. After forest tenure is clearly defined, it will be necessary to further ensure its long-term security and stability in order to effectively play an incentive role

and give farmers a "pill of confidence". It is necessary to ensure that certificates are issued to farmers to improve forest tenure in legal and factual dimensions. Through the implementation of management and use rights such as mortgage, circulation and logging, farmers' rights to benefit and disposal of forest resources will be guaranteed, and they will have enough room for management. Only in this way can the enthusiasm of farmers be fully mobilized and the efficiency of forestry management will be improved.

5.2.2 Develop differentiated policies according to forest management types to enhance the role of forest tenure in promoting management efficiency. According to forest management types, targeted differentiated policies should be discussed to meet the needs of farmers on forest tenure security. Economic forests and non-timber forests have short return on investment cycles, and farmers are more responsive to forest tenure security. The government should guide and encourage the circulation of forestland to improve the scale effect on the basis of stabling forest tenure, while giving appropriate financial and technical assistance to further promote the efficiency of forestry management. The main source of income for farmers who manage ecological public welfare forests is the ecological public welfare forest compensation, but it is a drop in the bucket. The compensation mechanism of ecological public welfare forests should be further improved, taking into account the level of economic development and the status forest resources of each region. Instead of adopting a "one-size-fits-all" policy, reasonable mechanism should be explored for the use of undergrowth resources in ecological public welfare forests. Establishing the adjustment and withdrawal mechanism of ecological public welfare forests and respecting the will of contracted management subjects are of great significance to improve the efficiency of forestry management.

5.2.3 Improve forestry supporting policies, strengthen the effect of the CFTR to assist in promoting forestry management efficiency. Supporting policies related to the CFTR play an important role in guiding farmers' forestry production and management, so further perfecting supporting policies can stimulate farmers' forestry production and consolidate the effect of increasing forestry income. In terms of forest tenure mortgage loans, the threshold for mortgage application should be appropriately lowered, the approval procedures should be simplified, the loan periods and interest rates should be rationalized to ease the financial tension of farmers in forestry production. In terms of forestry subsidies, there are some problems such as inconsistent standards, delayed payment or even unpopularity, so financial support needs to be increased. Especially in terms of ecological public welfare forest compensation, it is necessary to focus on social benefits while safeguarding ecological benefits. In terms of forestry insurance system, the government needs to play the role of service-oriented department, carry out policies tilt to forestry insurance companies and promote the establishment of forestry insurance market. At the same time, the government is supposed to guide farmers to improve their rational cognition of forest insurance products and reasonably avoid forestry management risks. In terms of forestry professional cooperatives, they can provide farmers with technological support and market docking services. They can also enhance the ability to absorb capital and improve farmers' risk resistance and market competitiveness by standardizing management and actively integrating resources. In terms of forestry technological services, it is necessary to vigorously promote the popularization of forestry technologies, carry out multi-type forestry science and technology services according to the types and characteristics of local forestry management, and finally meet the needs of farmers' forestry production and finally effectively improve the utilization efficiency of input factors in forestry.

5.2.4 Promote factors circulation and moderate scale management through government and market-led means to improve forestry management efficiency. In order to drive the transformation of forestry operation from traditional extensive management to intensive and efficient management, it is vital to promote the establishment of standardized forestland

circulation market and rational allocation of resources through scale management. As the most important management subjects in collective forest regions, farmers' forest management ways are not only related to the efficiency of forestry management, but also related to the sustainable development of forestry management in collective forest regions. The combination of a competent government and an effective market is the key to reverse the decentralization of forestland management and promoting moderate scale management of forestry. In order to reduce the production cost caused by fragmentation, improve the management efficiency and increase forestry income, the circulation and re-incorporation of forestland should be sped up. Under the policy of "Three rights separated" on the land tenure structure, moderate scale operation could be carried out, such as the promotion of family forestry. In addition to increasing government financial input, market-based financing channels should also be explored, and external social funds should be pulled in to realize the exchange of forest tenure and capital elements and solve the problem of insufficient funds and financing difficulties. Finally, the forestry labor force employment service market should be improved, and new types of farmers should be cultivated to improve the level of human capital in forestry. Besides, the flow of labor to deep processing and high value-added forestry industries should be facilitated. At last, in order to overcome the shortage of forestry labor caused by aging of rural labor force and labor migration, cooperatives may lead its members to engage in labour in the form of joint or mutual assistance.

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