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The Impact of Collective Forest Tenure Reform on Timber Production in China: An Empirical Analysis Based on Provincial Panel Data

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Abstract: China initiated a new collective forest tenure reform (CFTR) in 2003, which transferred the use rights of collective forest land and the ownership of collective trees to farmers. To assess the impact of the CFTR on timber production and to understand its underlying mechanisms, this study first conducted a theoretical analysis on how CFTR affects the production of commercial and non-commercial timber, leading to the provided hypotheses. Then, based on a panel dataset for 28 provinces from 1998 to 2018, a Time-varying Difference-in-Differences model was employed for empirical analysis. The results show that the CFTR led to an increase of 24.18% in commercial timber production and 34.37% in non-commercial timber production. The CFTR boosted the production of both types of timber initially, but the incremental effects were weakened over time. The incremental effects of the CFTR on commercial timber production was larger in regions with more collective forests. After the CFTR, the proportion of economic forest land in total forest land increased, contributing to a short-term rise in commercial timber production. In regions with higher timber market prices, reforms have a greater effect on increasing timber production, implying that farmers are more sensitive in their response to market values.

Keywords: collective forest tenure reform; timber production; commercial timber; non-commercial timber; China

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1. Introduction

In China, forest resources are classified based on the ownership of forest land into collective forests and state-owned forests. The former is owned by village collectives, the latter is owned by the state [1]. Collective forests are an important part of China's forest resources but also vital production assets for farmers. According to data from the National Forestry and Grassland Administration (2023), the area of collective forest land in China reaches 171.2 million hectares, accounting for about 60% of the total national forest area and involving over 100 million farming households. Collective forests provide 80% of the timber and more than 80% of the economic forest (intended for the production of fruits, edible oils, beverages, spices, industrial raw materials, and medicinal materials for the domestic market). The contribution of collective forests to the local and national economy of China is significant, especially in rural areas where forestry is the main source of income. In 2021, the total output value of China's forestry industry reached CNY 8.68 trillion (*China Forestry and Grassland Statistical Yearbook*, 2021).

In September 2020, China set the goals of achieving a "carbon peak" by 2030 and "carbon neutrality" by 2060. Forests, as one of the most effective carbon sinks in nature, play an important role in mitigating climate change and achieving carbon neutrality goals. The Chinese government has emphasized the importance of forest resources in its national carbon neutrality policy, planning to increase forest coverage and enhance forest carbon storage to achieve emission reduction targets. This not only contributes to global climate mitigation efforts but also provides a solid foundation for the improvement of China's ecological environment.

In China, collective forests, although comprising 60% of the total forested land, account for only 45% of the total forest stock [2]. These areas have long faced issues such as low productivity levels and a lack of active management by stakeholders [3]. To enhance the productivity and timber output of collective forest lands, China has implemented several reforms in the collective forest rights system [4]. In China, the property rights system for collective forests mainly refers to the property rights system of collective forest land and its trees. In March 1981, the Chinese government issued the "Decision on Several Issues Concerning the Protection of Forests and the Development of Forestry", which introduced policies such as stabilizing mountain and forest rights, defining reserved mountains, and establishing a forest production responsibility system, marking the beginning of reforms in the collective forest rights system. This reform initially distributed collectively owned forest lands and trees to family operations; but, due to unclear property rights and other issues, extensive deforestation occurred in the southern collective forest areas following policy implementation [5]. In June 1987, this process was halted. The government proposed that collectively owned timber forests (forests mainly aimed at producing wood and bamboo) in large tracts that were not yet divided among households should not be further divided; those already allocated should be managed collectively by the township or village, with dedicated personnel for forest protection. Farmers were encouraged to engage in various forms of joint logging, renewal, and afforestation. For collective forest areas, a policy of single-entity timber procurement was adopted. At the beginning of the 21st century, China initiated a new collective forest rights system reform (CFTR hereafter), contracting collectively owned forest lands to family operations and allocating collectively owned trees to family ownership, to enhance the operational performance of collective forest lands [6]. The CFTR began in Fujian Province in 2003 and was subsequently implemented in Jiangxi, Liaoning, Zhejiang, and other provinces. In 2008, China issued the "Opinions on Comprehensively Promoting Collective Forest Tenure Reform" to advance the CFTR nationwide [7]. By the end of 2011, China had completed the rights confirmation of 178 million hectares of collective forest land, with 97.8% of the collective forest land being managed by families (National Forestry and Grassland Administration, 2012). In September 2023, China issued the "Plan for Deepening Collective Forest Tenure Reform", continuing to deepen the reform and striving to establish a "clearly defined ownership, unified rights and responsibilities, strict protection, orderly transfer, and effective supervision of the collective forest rights system".

The CFTR has had various impacts on the input, output, and efficiency of forestry production factors. Existing studies have extensively explored its effects on the input of production factors and forestry income of households. Research has found that clear ownership rights have motivated households to invest more capital and labor in forestry production. Zhang et al. (2020) discovered that clear property rights encourage households to increase inputs like fertilizers and pesticides in forestry production [8]. Yi et al. (2014) found that the CFTR, through legal certification, strengthened the protection of forest rights, thereby encouraging forest investment [9]. Lin et al. (2020), based on empirical research using household data from 18 counties in China, indicated that the CFTR positively impacted forestry management investment [10]. On the other hand, some scholars, using empirical research from household surveys, have shown that the CFTR can increase households' input of production factors in the short term, but this effect gradually weakens over time [11,12]. Xie et al. (2016), using instrumental variable methods to control for factors other than the CFTR, examined the impact of the CFTR on afforestation, finding that the CFTR significantly increased the afforestation area by 7.68% in the same year, but the effect disappeared in subsequent years [13]. Some empirical studies have shown that the CFTR did not increase households' investment in forestry production. He et al. (2020) argued that the CFTR did not significantly enhance the level of forestry investment as expected [14–16].

Regarding the impact of the CFTR on household income, most existing studies believe that the CFTR has played a positive role in increasing household income and alleviating poverty [17–19]. Liu et al. (2017) found that the CFTR can optimize the input structure of forestry production factors, thereby enhancing households' forestry income [20]. Zhu et al. (2020) argued that stable transfer of rights helped to transfer forestry labor to non-agricultural industries, thus increasing non-agricultural income for households [18]. Thus, the CFTR has increased total household income by increasing both forestry and non-agricultural income. During this process, the proportion of forestry income in the total income of farming households has gradually increased. Liu et al. (2017b) demonstrated through survey data that the CFTR significantly increased both forestry income and total income for households [21]. However, Wei Jian et al. (2022) found in their study that the effect of the CFTR on increasing income varied significantly among households of different income levels, with a greater increase in income for wealthier households than for poorer ones [22]. Zang et al. (2015) showed that the CFTR gradually increased the income gap between households [23].

Timber is one of the most important forest products, yet existing research on how the CFTR impacts timber output is limited. Yin and Xu (2010), based on household survey data on average, found that each household in villages implementing the CFTR increased their timber harvesting by a total of 3.7 cubic meters over the study period [24]. Zhang and Buongiorno (2012), using panel data from 25 provinces in China, discovered that the CFTR increased China's timber supply by 10%–26% [25]. Initially, firewood remained an important source of energy for rural residents, so the CFTR also increased the output of firewood [19]. On the other hand, some studies argue that the CFTR suppressed the growth of timber production. For example, Liu et al. (2016) believed that, due to strict felling quota measures, timber production by households slowed down after the CFTR, while the development of non-timber forest products accelerated [2]. Zhu et al. (2020) argued that the CFTR also reduced timber harvesting by increasing non-agricultural employment among rural households [18].

Existing research on the impact of the CFTE in China primarily focuses on aspects such as the influence on the input of production factors and farmers' income. However, there is less study on the dynamic changes in timber yield, and the few studies that do address timber yield still require further refinement. Firstly, many empirical analyses on the impact of the CFTR on timber yield are based on household survey data, which may not accurately represent the situation before the CFTR, when collective forests were primarily managed by village collectives [26]. Post-CFTR, household management became a major player in forestry, significantly increasing the area of forest land managed by households [27,28]. Thus, using pre-CFTR and post-CFTR household data to explore the reform's impact on timber yield might be inaccurate. Additionally, most studies use data from the initial stages of the CFTR and attribute the increase in timber yield to property right incentives. However, the long production cycle in forestry and potential decrease in management enthusiasm due to land fragmentation post-reform suggest that the increase in timber production might be short-term. Furthermore, timber is classified into commercial (sold in the market) and non-commercial types (used by farmers but not sold, such as building materials and firewood). Studies focusing on total timber yield might be biased, as households may manage commercial and non-commercial timber differently under the CFTR.

In summary, existing research on the impact of the collective forest tenure system reform on timber production is still insufficient. Our study aims to address these limitations using village collective timber production data combined with long-term provincial panel data from 1998 to 2018. By distinguishing between commercial and non-commercial timber, this paper provides a more detailed understanding of the CFTR's differential impacts on various types of timber production, thereby filling a gap in existing research. This study hopes to further deepen CFTR in China and improve the resource allocation efficiency of collective forest land.

The structure of this article is as follows: the first part is the introduction and literature review; the second part is the theoretical analysis and research hypothesis; the third part is the empirical strategy; the fourth, fifth, and sixth parts are the empirical results; the seventh part is discussion; and the last is the conclusion.

2. Theoretical Analysis and Research Hypotheses

The collective forest tenure system in China encompasses the ownership of forest land, the right to use forest land, and the ownership of trees. China's CFTR began with pilot programs in 2003, full implementation in 2008, and was substantially completed by 2011. The core of this reform was the transition of forestland use rights (contracting and operational rights) and tree ownership from collectives to farming households; after the CFTR, households acquired the use rights of collective forest land and ownership of the trees.

The CFTR led to a transformation in the management of collective forests. Before the CFTR, collective forests were uniformly managed by collectives, which often resulted in underinvestment, low production efficiency, and rampant illegal logging. After the CFTR, these collective forests were managed by farming households, which differed from the collective model, thereby impacting timber output, both commercial and non-commercial. Commercial timber refers to wood sold in the market, while non-commercial timber primarily refers to the wood used by farmers for their own purposes rather than for sale in the market, including materials for house construction, firewood, etc. (National Forestry and Grassland Administration, 2015). Here, we analyze the impact of the CFTR on the production of both commercial and non-commercial timber in collective forests.

2.1. Impact of Collective Forest Tenure Reform on Commercial Timber Production

The CFTR assigned the usage rights of collective forestland and the ownership of collective forest trees to operational entities such as farming households. This shift from collective to family management of collective forests is expected to impact the production of commercial timber in multiple ways. Figure 1 showed the impact mechanism of the CFTR on commercial timber production.

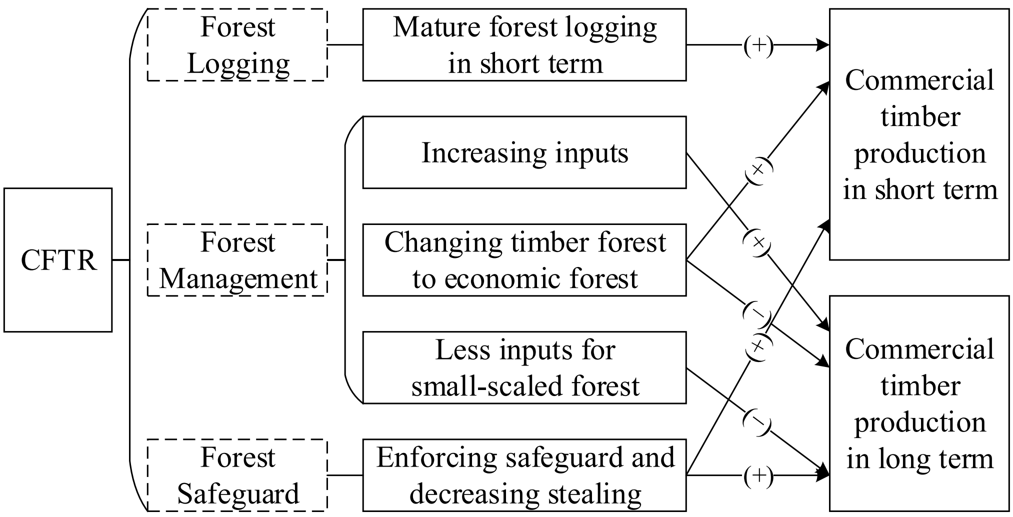

Figure 1. The impact mechanism of the collective forest tenure reform on commercial timber production. Note: (+) implies a positive direction of impacts and (−) a negative direction.

Firstly, after the CFTR, farming households have obtained the right to use forest land and ownership of forest trees; the content of the right is more complete, leading to increased enthusiasm for their management and disposal [29–31]. At the beginning of the CFTR, some trees acquired by households were mature for logging; compared to village collectives, households often prefer liquidity, thus tending to sell their timber resources for economic benefits. Moreover, the CFTR typically being a collective action resulted in uniformity in logging behavior among households, which means that suitable forests are usually harvested, leading to a short-term increase in commercial timber production.

Secondly, over time, households' management behaviors diversified after the CFTR, leading to effects like increased investment due to property right incentives, changes in forest species composition, and reduced inputs due to smaller forest scales. Some households, incentivized by property rights, increased forestry production investment, thereby enhancing forest stock and commercial timber production [29–31]. Others, under market influences, converted timber forests into more profitable economic forests, initially boosting commercial timber production [32]. However, once economic forests reach saturation, this production increase effect will dissipate. An increased proportion of economic forests, leading to reduced timber forest areas, will decrease commercial timber production in the long term. Some households might reduce or even cease their forestry inputs, leaving their allocated forest land and trees idle due to small land scales, high labor costs, and low forestry returns, reducing forest stock and commercial timber production compared to collective management. For instance, from 1978 to 2014, labor prices rose 16.47 times, while timber prices only increased by 69.78% from 1979 to 2016 (real terms) [3]. The long-term impact of the CFTR on commercial timber production has both positive and negative aspects. The negative impact may be greater for commercial timber forests, as many households reduced or did not invest in forestry production [33]. One evidence is that, after the CFTR, only about 10% of forest land experienced transfer activities [34]. Thus, in the long term, the increased production effect of the CFTR on commercial timber is expected to weaken.

Finally, after the CFTR, through improved forest resource management and reduced illegal logging, commercial timber production increased. After the CFTR, collective forests, managed by households with clear property rights, had strengthened supervision, significantly reducing illegal logging. Previously, illegally logged timber was not included in commercial timber production statistics. Therefore, the reduction in illegal logging has been converted into official commercial timber production, further increasing its output.

In summary, households' pursuit of quick economic returns, adjustments in forest land utilization, and the reduction in illegal logging have promoted a short-term increase in commercial timber production. Some households, under property right incentives, increased forestry production inputs, leading to a long-term increase in commercial timber. However, changes in forest land utilization and some households leaving their land idle due to small scales will decrease commercial timber production in the long term, potentially leading to a downward trend. Based on this, the following two hypotheses are proposed:

Hypothesis 1: *After the CFTR, commercial timber production will initially increase, followed by a decrease.*

Hypothesis 2: *After the CFTR, farming households will convert timber forests into economic forests, thereby increasing commercial timber production in the short term.*

2.2. Impact of Collective Forest Tenure Reform on Non-Commercial Timber Production

The CFTR also affects the production of non-commercial timber. Before the CFTR, households typically obtained non-commercial timber, used for construction and firewood, from collectively managed forests. Under this system, besides investing labor, farmers had to comply with collective forest management regulations, such as applying to the village collective or paying certain fees [35]. Due to these restrictions, households' needs for non-commercial timber were often unmet. After the CFTR, households began to harvest non-commercial timber from their contracted forests, free from the constraints of applying to the village collective or paying fees. Therefore, in the initial stages of the CFTR, households would harvest more timber for self-constructed housing, renovations, and firewood preparation, thus satisfying their production and living needs, leading to a short-term increase in non-commercial timber production. Moreover, before the CFTR, some households acquired non-commercial timber through illegal logging [36], which was not accounted for in the statistics. After the CFTR, households' legal harvesting of non-commercial timber from their own forests was included in the statistical data, resulting in an apparent increase in non-commercial timber production. In the long term, households' harvesting of non-commercial timber mainly aims to satisfy family production and living needs. Once these needs are met, the production of non-commercial timber tends to stabilize. Therefore, the CFTR has no significant long-term impact on non-commercial timber production. Based on the above analysis, the following hypothesis is proposed:

Hypothesis 3: *After the CFTR, non-commercial timber production will increase in the short term but will have no impact in the long term.*

2.3. The Impact of Timber Market Prices and Forest Reform on Timber Production

The impact of the CFTR on the production of commercial and non-commercial timber is moderated by timber market prices. With the deepening of China's market-oriented reforms, the timber market mechanism in China has gradually improved. In 1993, China deregulated timber trading, establishing a market mechanism for timber trading [12]. After the CFTR, farming households gained more stable tenure to forest land and timber revenue, and the government further relaxed conditions for commercial forest logging, reducing related taxes and management fees [37]. In this new institutional environment, households, as the decision makers in the production and management of collective forests, show higher sensitivity to market price fluctuations. When timber market prices rise, households tend to increase the production of commercial timber and are inclined to reduce the production of non-commercial timber, converting it into commercial timber for higher economic gains. Thus, an increase in timber market prices strengthens the CFTR's effect on increasing commercial timber production while weakening its effect on non-commercial timber production.

Based on the above analysis, the following hypothesis is proposed:

Hypothesis 4: *An increase in timber market prices strengthens the CFTR's effect on increasing commercial timber production and weakens its effect on non-commercial timber production.*

3. Methodology

3.1. Model Specification

3.1.1. Baseline Regression Modeling

Given the variation in the timing of the CFTR across different provinces, and drawing from the modeling approaches of Li et al. (2016) [38] and Zhou et al. (2019) [39], a Time-varying Difference-in-Differences (DID) model is constructed. This model effectively addresses endogeneity issues, such as reverse causality. The econometric regression model is set as follows:

$$\mathrm{Product_{it}} = \beta_0 + \beta_1 \mathrm{did_{it}} + \lambda \mathrm{Control_{it}} + \nu_t + \mu_i + \varepsilon_{it}\ . \quad (1)$$

In Equation (1), i represents the province and t represents the year. The dependent variable $\mathrm{Product_{it}}$ denotes the timber production (commercial/non-commercial) of province i in year t, and the model employs a logarithmic form. $\mathrm{did_{it}}$ is the DID estimator; if province i starts implementing the CFTR in year t, then for the years following t in province i $\mathrm{did_{it}} = 1$; otherwise, it is 0. The coefficient β_1 measures the impact of the CFTR on timber production. $\mathrm{Control_{it}}$ includes a series of control variables. ν_t denotes year fixed effects, controlling for the effects of time trends. μ_i represents province fixed effects, accounting for factors at the provincial level that do not change over time and their impact on timber production. ε_{it} is the random disturbance term.

3.1.2. Parallel Trends Test and Dynamic Effects Modeling

Based on the baseline model (1), the following model is established to test the parallel trends assumption and to observe the persistence of the impact of the CFTR on timber production:

$$\text{Product}_{\text{it}} = \alpha_0 + \prod_{\text{k} \geq -4}^{7} \alpha_{\text{k}} \text{D}_{\text{it}}^{\text{k}} + \lambda \text{Control}_{\text{it}} + \nu_{\text{t}} + \mu_{\text{i}} + \varepsilon_{\text{it}}. \tag{2}$$

In Equation (2), $\text{D}_{\text{it}}^{\text{k}}$ represents the dummy variable for the event of the CFTR. Assuming the year of the CFTR undertaken by the province i is y_{i}, let $\text{k} = \text{t} - \text{y}_{\text{i}}$. For this study, the four years before the implementation of the policy are considered for testing parallel trends, where $\text{D}_{\text{it}}^{\text{k}} = 1$ for $\text{k} \leq -4$ and is otherwise 0. Similarly, for $\text{k} = -3, -2, \cdots, 5$, and 6, the corresponding $\text{D}_{\text{it}}^{\text{k}} = 1$ and is otherwise 0. For $\text{k} \geq 7$, $\text{D}_{\text{it}}^{\text{k}} = 1$ and is otherwise 0. By comparing the economic and statistical significance of the parameters α_{k} in Equation (2), the temporal changes in the impact of the CFTR on timber production can be tested.

3.1.3. Placebo Test Modeling

In order to rule out whether the impact of the CFTR on timber production is influenced by other unobserved omitted variables, an indirect placebo test is conducted, following the approach of Chetty et al. (2009) [40] and La Ferrara et al. (2012) [41]. Firstly, the expression for coefficient $\hat{\beta}_1$ from model (1) can be derived as

$$\hat{\beta}_1 = \beta_1 + \lambda \frac{\text{cov}(\text{did}_{\text{it}}, \varepsilon_{\text{it}} | \text{W})}{\text{var}(\text{did}_{\text{it}} | \text{W})}. \tag{3}$$

In the equation, W represents all control variables and fixed effects and λ represents the impact of unobserved factors on the dependent variable. If $\lambda = 0$, unobserved factors do not affect the estimation result, implying that $\hat{\beta}_1$ is unbiased. This cannot be directly verified, so an indirect placebo test method is used. The logic is to find a theoretically irrelevant variable to replace did_{it}, where $\beta_1 = 0$. If this incorrect estimation variable actually affects the result, i.e., $\hat{\beta}_1$ is not zero, it implies that the estimation equation is incorrect, indicating that other characteristic factors affect the estimation result. Specifically, this study randomly generates lists of provinces and reform times for the CFTR, creating an incorrect estimate $\hat{\beta}_1^{\text{random}}$. This process is repeated 1000 times, generating 1000 $\hat{\beta}_1^{\text{random}}$ values. The distribution of $\hat{\beta}_1^{\text{random}}$ is examined to determine if the placebo test is passed. If $\hat{\beta}_1^{\text{random}}$ is distributed near to zero and follows a normal distribution it can be inferred that $\lambda = 0$, indicating that unobserved factors do not affect the estimation result.

3.1.4. Mediating Effects Modeling

Based on the theoretical analysis previously presented, this study selects forest product structure adjustment as the mediating variable and constructs the path "CFTR (X)—Forest Land Structure Adjustment (M)—Increase in Commercial Timber Production (Y)" for mechanism analysis. M stands for "Farmers have shifted from planting timber forests to planting economic forests". Following the method of Chen et al. (2020) [42], the study first directly regresses the mediating variable (M) against the core independent variable (X); in the second step, the effect of the mediating variable (M) on the outcome variable (Y) primarily relies on relevant theory and the literature. Based on this, the regression model is as follows:

$$\text{Structure}_{\text{it}} = \alpha_0 + \alpha_1 \text{did}_{\text{it}} + \lambda \text{Control}_{\text{it}} + \nu_{\text{t}} + \mu_{\text{i}} + \varepsilon_{\text{it}}. \tag{4}$$

In Equation (4), $\text{Structure}_{\text{it}}$ represents the forest land structure adjustment status of province i in year t. Other variables are consistent with the baseline model (1).

3.2. Variables

1. Dependent Variables

- Commercial Timber Production. According to the "China Forestry Statistics Indicator Explanation", commercial timber production as per production units can be categorized into the following: (1) Timber produced by state-owned enterprises within the system; (2) Timber produced by state-owned forest farms and institutions within the system; (3) Timber harvested by system-external enterprises and institutions from their own forest land; (4) Timber produced by township (town) collective enterprises and institutions; (5) Timber produced by villages and lower-level organizations and individual farmers. The commercial timber production indicator is most relevant to the CFTR and to the timber produced by villages and lower-level organizations and individual farmers. Policies of the CFTR that distribute mountain forests to households or share profits equally have transferred collective forest land to households within villages. The commercial timber production by village-level organizations and households measures the change in commercial timber production affected by the CFTR. Hence, in this study, the commercial timber production refers to the timber production by villages and lower-level organizations and individual farmers.
- Non-commercial timber production. Non-commercial timber refers to the wood harvested by households, organizations, and individuals for the production and life of farmers for their own use, which cannot be circulated or sold in the market. The non-commercial timber production in this paper is the sum of timber for farmers' own use and firewood.

2. Explanatory Variable: The core explanatory variable is whether the CFTR was implemented. Referring to the CFTR times recorded by He et al. (2021) [43] and verifying using the "*China Forestry Yearbook*", the time of the CFTR for each province is determined based on the start time of pilot programs and the time when provincial governments issued reform opinions. Once a province begins to implement the CFTR, the dummy variable is assigned a value of 1; otherwise, it is 0. Specific CFTR years are shown in Table 1.

Table 1. The year each province began implementing the CFTR.

Year of CFTR	Provinces, Cities and Autonomous Regions
2003	Fujian Province
2004	Jiangxi Province
2005	Liaoning Province
2006	Zhejiang, Hebei, Yunnan, Hubei, and Guizhou Provinces
2007	Anhui Province, Henan Province, Sichuan Province, Hunan Province, Shaanxi Province, Jilin Province, Guangxi Zhuang Autonomous Region, and Hainan Province
2008	Beijing, Shaanxi Province, Inner Mongolia Autonomous Region, Heilongjiang Province, Jiangsu Province, Chongqing Municipality, Gansu Province, and Qinghai Province
2009	Shandong Province, Guangdong Province, and Ningxia Hui Autonomous Region
2010	Xinjiang Uighur Autonomous Region

Note: The timing of the CFTR in various provinces and cities was determined based on the principle of regional pilot projects taking the lead. Relevant information was collected and organized from the *China Forestry Yearbook* and various provincial forestry websites.

3. Mediating Variable: As deduced from the theoretical analysis above, the CFTR has given farming households greater autonomy. Considering the maximization of benefits, some households tend to convert timber forests into economic forests, adjusting forest land structure, thereby increasing short-term timber production. Therefore, the adjustment in the forest land structure is a mediating variable through which the

CFTR impacts timber production. In an ideal scenario, the structure of forest land is represented by the ratio of the areas of economic forests to timber forests. However, due to data availability, this paper instead uses the ratio of their output values to represent this structure. Specifically, use the ratio of the output value of economic forest products' planting and harvesting to the output value of bamboo and timber harvesting by villages, lower-level organizations, and individual farmers (calculated by multiplying the volume of bamboo and timber harvested by these entities by the price of these woods) from the "*China Forestry Statistical Yearbook*" to represent the forest land structural adjustment.

4. Control Variables: the control variables include aspects of natural characteristics, forest resource endowment, and rural socio-economic characteristics.
   - For natural characteristics, average temperatures of provinces, represented by major city average temperatures, are used. For commercial timber, suitable temperature and light conditions are beneficial for the growth of trees. For non-commercial timber, firewood, an important heating resource, is used more in lower temperatures.
   - For forest resource endowment, the live standing timber stock per unit of forest land area in each province is selected, represented by the ratio of live standing timber stock to forest land area.
   - For rural socio-economic characteristics, variables include rural household characteristics and rural economic characteristics. Rural household characteristic variables include the educational level of households, income level of households, and rural population size. The higher the education level of households, the more job choices they have, reducing the likelihood of engaging in forestry management, thereby affecting timber production. The higher the income level of households, the less likely they are to engage in forestry management of land with low returns and long cycles, also affecting timber production. The size of the rural population directly impacts timber production, with fewer rural populations leading to fewer young and middle-aged laborers, reducing the likelihood of timber harvesting. Rural economic characteristics include industrial activities, housing structure, energy structure, and transportation conditions. Regarding industrial activities, grain and agricultural production occupy a lot of land, thereby affecting timber production. For housing structures, some rural houses opt for brick and wood structures, affecting the production of timber, especially non-commercial timber. In terms of energy structure, with the improvement in rural infrastructure, the energy consumption structure of households is gradually transforming, with increasing rural electricity usage, which also affects the production of timber, especially firewood. Regarding transportation conditions, the convenience of transportation is an important base factor of socio-economic development, represented here by the per capita rural road length. Moreover, the socio-economic development of cities in the urban–rural relationship is also an essential base factor, represented by urban residents' wage levels, calculated using the CPI-adjusted average wage of on-post urban employees.

3.3. Data Sources and Descriptive Statistics

In terms of data sources, for dependent variables, commercial and non-commercial timber production data come from the "*China Forestry Statistical Yearbook*"; the explanatory variable representing the timing of the CFTR comes from the "*China Forestry Yearbook*" and official news from the National Forestry and Grassland Administration; control variables such as the educational level of rural households, rural population size, disposable income of households, rural electricity usage, and the area of new rural housing with brick and wood structures come from the "*China Rural Statistics Yearbook*"; average wages of urban employees on-post, per capita rural road length, grain production, and average annual temperatures are from the "*China Statistical Yearbook*"; live standing timber stock is from the "Forest Resources Inventory Report", and timber market prices are from the "*China Forestry Statistical Yearbook*". The mediating variable of forest land structure adjustment is a constructed variable, namely the ratio of the output value from the planting and harvesting of economic forest products to the output value of bamboo and timber harvesting, which is conducted by villages, lower-level organizations, and individual farmers. Both variables involved are sourced from the "*China Forestry Statistical Yearbook*". The moderating variable of timber market prices is the actual average selling price of timber products, sourced from the "*China Forestry Statistical Yearbook*".

To ensure data comparability, the disposable income of rural residents and the average wage of urban employees on-post are converted to constant 1998 prices using the CPI index. To mitigate heteroscedasticity problems, logarithmic transformations are applied to related variables. The meanings and preprocessing of relevant variables are shown in Table 2.

Table 2. The definitions of variables and their preprocessing.

Category	Variables	Definitions and Assignment	Preprocessing
Dependent Variables	Commercial Timber Production (Y1)	Timber production by villages, lower-level organizations, and individual farmers (million cubic meters)	Logarithm transformation
	Non-Commercial Timber Production (Y2)	Total amount of timber harvested by farmers for personal use and firewood (million cubic meters)	Logarithmic
Explanatory Variable	Whether CFTR (did)	Indicates whether the CFTR has been implemented (Yes = 1; 0 = otherwise)	Assign 0 or 1
Mediating Variable	Forest Land Structure Adjustment (Struc)	Ratio of the output value of economic forest products to the value of bamboo and timber harvesting by villages, lower-level organizations. and individual farmers (no unit)	None
Control Variables	Education Level (Edu)	The number of people with high school level education or above per hundred labor force (people)	Logarithm transformation
	Rural Population (Popu)	Rural population size in each region (10,000 people)	Logarithm transformation
	Disposable Income of Households (Rincome)	Disposable income of households in each region (yuan/person)	Logarithm transformation converted to constant 1998 prices using the CPI index
	Rural Transportation Convenience (Road)	Per capita rural road length in each region (kilometers/person)	Logarithm transformation
	Average Temperature (Tem)	Average annual temperature in each region (degrees Celsius)	None
	Grain Production (Grain)	Grain production in each region (10,000 tons)	Logarithm transformation
	Forest Resource Accumulation (Accum)	Live standing timber stock per unit area in each region (hectares/cubic meter)	Logarithm transformation
	Urban Resident Wage Level (Wages)	Average wage of on-post urban employees (CNY)	Logarithm transformation and converted to constant 1998 prices using the CPI index
	New Rural Brick–Wood Structure Area per Person (Square)	Average per capita area of new rural housing with brick and wood structures built within a year (square meters/person)	Logarithm transformation
	Rural Electricity Consumption (Electric)	Rural electricity consumption by region (billion kWh)	Logarithm transformation

We constructed panel data for 28 provinces (cities and districts) from 1998 to 2018. Tianjin, Shanghai, and Tibet were not included due to significant data gaps. The data range for commercial timber production is 1998 to 2018. The data range for non-commercial timber production is 2003 to 2018, as the *China Forestry Statistical Yearbook* began recording this data only from 2003. Descriptive statistics of related variables are shown in Table 3.

Table 3. Descriptive statistics of variables.

Category	Variable	Unit	Sample Size	Mean	Standard Deviation	Minimum	Maximum
Dependent Variables	Commercial Timber Production	10,000 cubic meters	588	136.8	231.2	0.05	2389
	Non-Commercial Timber Production	10,000 cubic meters	448	104.6	206.9	0.01	1332
Explanatory Variable	CFTR Implementation	Unitless	588	0.566	0.496	0	1
Mediating Variable	Forest Land Structure Adjustment	Unitless	504	143.01	374.23	1.2138	3283.72
Dependent Variables	Education Level	People	588	14.84	6.622	4.79	52.42
	Rural Population	10,000 people	588	2647	1769	247.7	8001
	Disposable Income of Households	Yuan/person	588	6583	6837	1294	85,174
	Rural Transportation Convenience	kilometers/person	588	62.55	93.79	5.205	1853
	Average Temperature	degrees centigrade	588	14.55	5.115	4.3	25.4
	Grain Production	10,000 tons	588	1946	1488	34.14	7616
	Forest Resource Accumulation	Hectares/m^3	588	39.97	23.61	3.496	116.5
	Urban Resident Wage Level	Yuan	588	34,742	24,323	5384	152,035
	New Rural Brick–Wood Structure Area per Person	Square meters/person	448	0.264	0.226	0.01	1.39
	Rural Electricity Consumption	billion kWh	448	226.5	351.6	2.9	1933

Note: Missing values are filled in using interpolation. The data in this table are presented as raw figures and are not log-transformed.

In the dataset of this paper, the trend in timber production in 28 provinces of China from 1998 to 2018 is shown in Figure 2. Commercial timber production started from a low level in 1998 and experienced fluctuating growth. Before 2002, production was low, then it rapidly increased until 2003. From 2003 to 2018, commercial timber production fluctuated but showed an overall upward trend. The production of non-commercial timber in China from 2003 to 2018 generally showed a fluctuating downward trend, with a trough in 2005 and a peak in 2008. The decline in non-commercial timber reflects the reduction in timber consumption for house construction and firewood due to socio-economic development in rural China. Additionally, the sharp rise in commercial and non-commercial timber in 2008 might be related to the La Niña phenomenon in 2007, which caused extreme low temperatures, rain, snow, and freezing natural disasters in China.

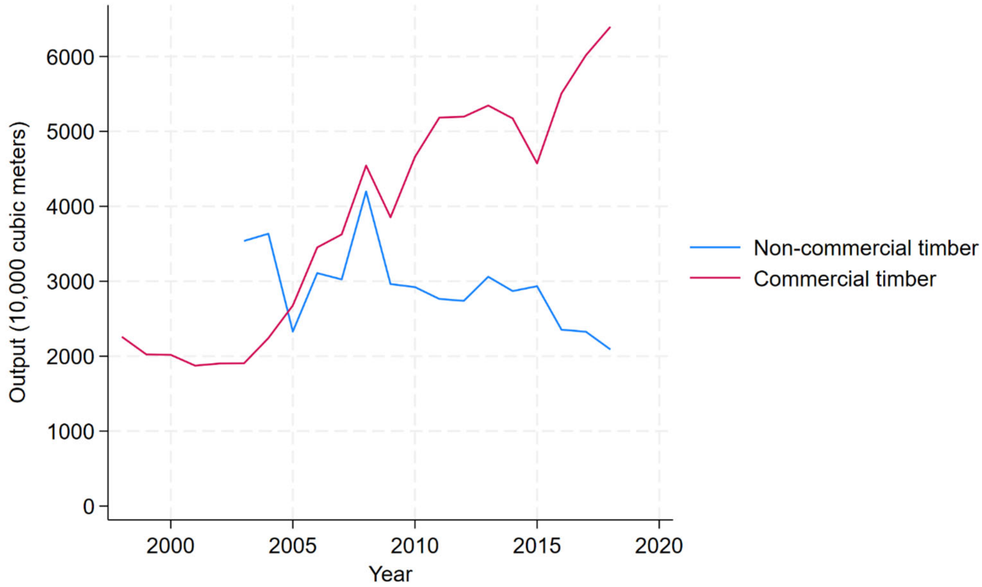

Figure 2. Commercial and non-commercial timber production in China from 1998 to 2018.

4. Empirical Results for Commercial Timber Production

4.1. Baseline Regression

The baseline regression results regarding the impact of the CFTR on commercial timber production are presented in Table 4. The regressions in columns (1) to (4) include clustered robust standard errors to control for autocorrelation. Column (1) shows that, without any control variables, the CFTR led to a 28.07% increase in commercial timber output, which is statistically significant at the 1% level. In column (2), with other control variables included, the impact of the CFTR on commercial timber production remains significant at the 5% level, consistent with expected results. The implementation of the CFTR leads to an approximate 24.18% increase in commercial timber production for provinces, a notable increase for household commercial timber production within a province. Columns (3) and (4) present the baseline regression excluding data affected by weather conditions in 2008. The coefficients in these columns are larger than those in the baseline regression without the removal of the unusual fluctuations, indicating that in years with normal weather conditions the CFTR still has a positive effect on commercial timber production. The baseline regression analysis indicates that the CFTR has overall increased the production of commercial timber, consistent with Hypothesis 1.

Table 4. Baseline regression results for commercial timber production.

	(1)	(2)	(3)	(4)
	Full Sample	**Full Sample**	**Excluding 2008**	**Excluding 2008**
did	0.2807 ***	0.2418 **	0.3077 ***	0.2788 **
	(0.1062)	(0.1111)	(0.1146)	(0.1224)
lnedu		0.0816		0.0227
		(0.3391)		(0.3484)
lnpopu		1.0848 **		1.0586 *
		(0.5436)		(0.5508)
lnrincome		0.2445 ***		0.2391 **
		(0.0890)		(0.0931)

Table 4. *Cont.*

	(1)	(2)	(3)	(4)
	Full Sample	**Full Sample**	**Excluding 2008**	**Excluding 2008**
lnroad		−0.0033		0.0168
		(0.1371)		(0.1322)
tem		0.0020		0.0009
		(0.0067)		(0.0069)
lngrain		−0.1559		−0.1892
		(0.1927)		(0.1956)
lnwages		0.2042		0.4881
		(0.4770)		(0.4966)
lnaccum		0.7363 *		0.7098 *
		(0.3855)		(0.3918)
_cons	3.5507 ***	−10.4961 **	3.5270 ***	−12.7504 ***
	(0.0643)	(4.8264)	(0.0678)	(4.9113)
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	588	588	560	560
adj. R2	0.8631	0.8649	0.8597	0.8616

Note: ***, **, and * are significant at the 1%, 5%, and 10% statistical levels, with standard errors in parentheses.

4.2. Parallel Trend Test and Dynamic Effects Analysis

A crucial prerequisite for employing the Time-varying Difference-in-Differences (DID) method is that the provinces implementing the CFTR (treatment group) and those yet to be affected by the CFTR (control group) must exhibit no significant differences or a common growth trend in commercial timber production before the CFTR. Using the year before the policy implementation as the baseline, the common trend hypothesis was tested using Equation (2), and the results are depicted in Figure 3. Prior to the CFTR, the confidence interval for the regression coefficient includes zero, indicating that the coefficient is not significant and that the treatment and control groups exhibited the same trends in commercial timber production before the policy implementation, thereby passing the parallel trend test. This demonstrates that our baseline regression results are robust.

Figure 3 also allows for the observation of the persistence of the impact of the CFTR on timber production. It is evident that, from the second year after the implementation of the CFTR to the sixth year, the CFTR significantly increased the commercial timber production of the provinces. However, starting from the seventh year, the impact of the CFTR on commercial timber production in the provinces becomes insignificant. Overall, as the duration of the CFTR increases, its impact on commercial timber production in the provinces undergoes a process of first increasing and then decreasing, reaching its maximum in the fourth year after implementation and disappearing by the seventh year. It is evident that post-CFTR the production of commercial timber first increased and then decreased, with the impact lasting only seven years. The baseline regression results and dynamic effect analysis collectively validate Hypothesis 1.

4.3. Robustness Tests

4.3.1. Placebo Test

To rule out the impact of the CFTR on commercial timber production being influenced by other omitted variables and random factors, a placebo test was conducted following the method of La Ferrara et al. (2012) [37]. Randomly 'selecting' provinces that participated in the CFTR and generating random reform times, a reform time–province, two-level random experiment was constructed. Regression was conducted according to Equation (1), and this process was repeated 1000 times. The distribution of the regression coefficients of the did variable from these virtual experiments was used to determine the reliability of the baseline regression results. The probability density graph of the regression coefficients of the did variable from these 1000 regressions is shown in Figure 4, where the vertical dashed line on the right represents the regression coefficient of the did variable in the baseline regression. The graph indicates that the regression coefficients follow a normal distribution with a mean of 0.0145, close to zero, and much smaller than the baseline regression's coefficient of 0.2418. Therefore, the regression results of this study are not affected by other random factors. In other words, arbitrarily set reform times and provinces for the CFTR have no impact on commercial timber production, which in turn suggests the genuine impact of the CFTR on commercial timber production.

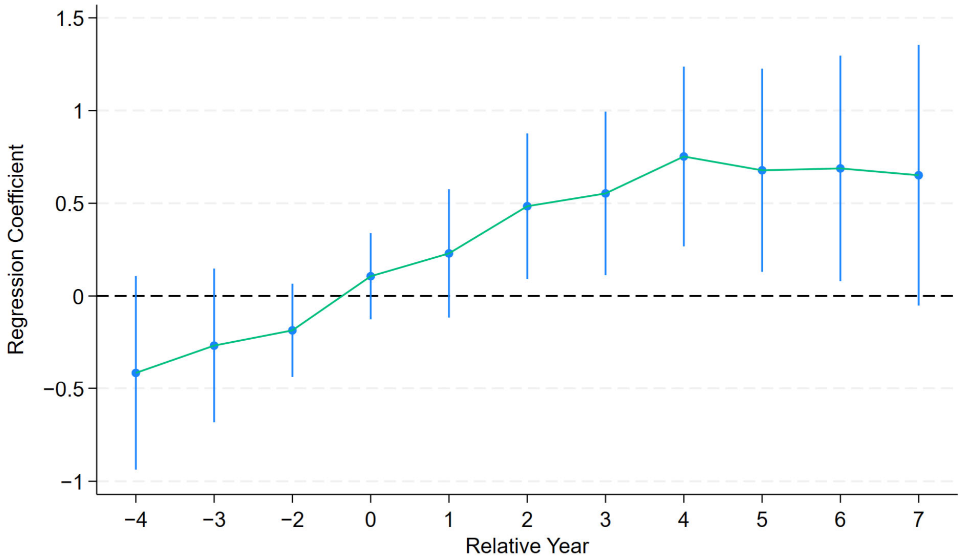

Figure 3. Parallel trend test and dynamic effect analysis for commercial timber production. Note: the dots represent regression coefficients, and the vertical lines represent the 95% confidence intervals.

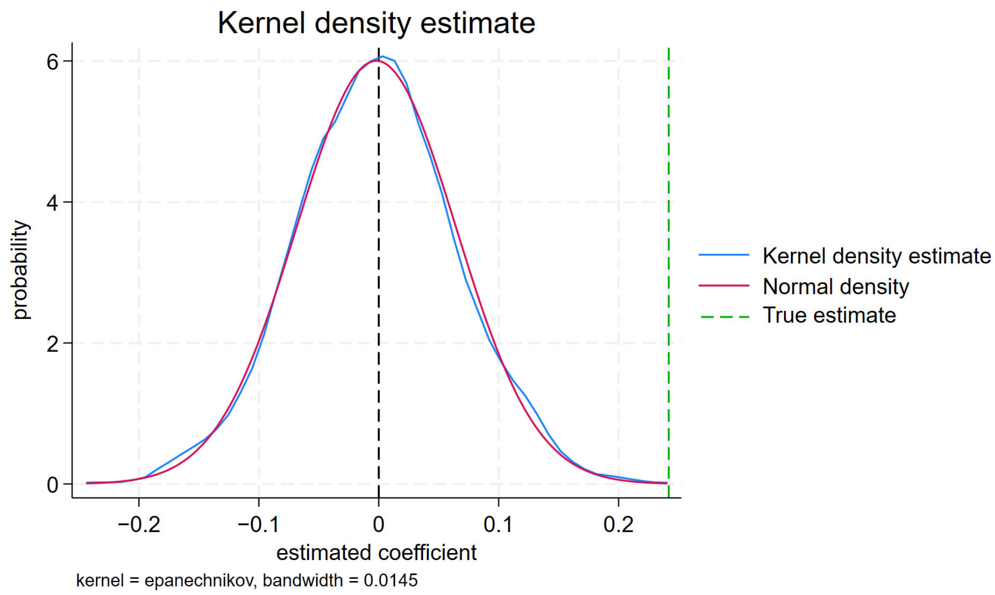

Figure 4. Results of the placebo test for commercial timber production.

4.3.2. Excluding the Impact of Other Policies

Although the above tests further strengthen the robustness of the regression results, other policies implemented concurrently with the CFTR might also affect commercial timber production, leading to biases in the regression results. The impact of China's Natural Forest Protection Program (NFPP) measures on timber production has been emphasized in many studies. These measures include the protection of forest resources and constraints on timber production. In 2000, the State Council approved the "Implementation Plan for Natural Forest Resources Protection Project in the Upper Reaches of the Yangtze River and the Middle and Upper Reaches of the Yellow River". The NFPP covered six provinces (regions and cities) in the upper reaches of the Yangtze River—Yunnan, Sichuan, Guizhou, Chongqing, Hubei, and Tibet—and seven provinces (regions) in the middle and upper reaches of the Yellow River—Shaanxi, Gansu, Qinghai, Ningxia, Inner Mongolia, Shanxi, and Henan. These areas prohibited the commercial logging of natural forests, impacting timber production. Therefore, it is necessary to exclude the impact of the NFPP reform. One method is to add an NFPP implementation dummy variable to the model in Equation (1), with regression results shown in Table 5, column (1). It is observed that the CFTR resulted in a 24.5% increase in commercial timber production, significant at the 5% level. It is evident that the CFTR still has a significant positive impact on commercial timber production. This indicates that, even after controlling for the impact of the NFPP on timber production, the increased production effect of the CFTR remains very pronounced.

Table 5. Regression results excluding the impact of other policies.

	(1)	(2)
	Incorporate the Dummy Variable for the NFPP	**Exclude Provinces Where the NFPP Is Implemented**
did	0.2450 **	0.5487 ***
	(0.1114)	(0.1316)
project	0.7000 **	
	(0.2844)	
lnedu	0.0966	−0.2509
	(0.3328)	(0.4259)
lnpopu	0.9357 *	−1.4243 ***
	(0.5328)	(0.5029)
lnrincome	0.2249 **	−0.1964
	(0.0872)	(0.2804)
lnroad	−0.0068	0.1333
	(0.1369)	(0.1136)
tem	−0.0009	0.0043
	(0.0068)	(0.0083)
lngrain	−0.2479	−0.0898
	(0.1938)	(0.2353)
lnwages	0.2084	0.5289
	(0.4766)	(0.5772)
lnaccum	0.7372 **	1.4450 ***
	(0.3687)	(0.4047)
_cons	−8.8644 *	6.7477
	(4.8608)	(5.4587)

Table 5. *Cont.*

	(1)	(2)
	Incorporate the Dummy Variable for the NFPP	**Exclude Provinces Where the NFPP Is Implemented**
Province FE	Y	Y
Year FE	Y	Y
N	588	315
adj. R2	0.8673	0.9290

Note: ***, **, and * are significant at the 1%, 5%, and 10% statistical levels, with standard errors in parentheses.

The second approach involves excluding provinces affected by the NFPP. After removing 13 provinces impacted by the implementation of the NFPP, the baseline regression method was applied, and the results are presented in Table 5, column (2). The CFTR has led to a 54.87% increase in the production of commercial timber, which is significant at the 1% level. It is evident that, compared to the baseline regression, the increase in commercial timber production due to the implementation of the CFTR remains significant even after excluding the provinces affected by the NFPP. Moreover, the increase in production is greater, further demonstrating the robustness of the baseline regression results.

4.4. Heterogeneity Analysis

While the baseline regression results have already shown that the CFTR can increase the production of commercial timber, it is important to note that the distribution of collective forests across provinces in China is uneven. According to the "China Forest Resources Report (2014–2018)", the three provinces with the highest proportion of collective forests are Zhejiang, Guizhou, and Hunan, with respective collective forest area ratios of 96.28%, 96.14%, and 94.89%. Conversely, the three provinces with the lowest proportions are Heilongjiang, Xinjiang, and Qinghai, with respective ratios of 4.59%, 10.80%, and 16.97%. Given these significant differences in collective forest area ratios among provinces, it can be anticipated that in provinces with higher proportions of collective forest the effect of the CFTR on increasing commercial timber production is more intense. Therefore, this section conducts a heterogeneity analysis from the perspective of collective forest resource abundance. The provinces are divided into two groups based on the proportion of collective forest land area to total forest land area, and the baseline regression model (1) is applied separately to each group. The regression results are presented in Table 6.

Table 6. Heterogeneity regression results in terms of collective forest richness.

	(1)	(2)
	Rich in Collective Forests	**Poor in Collective Forests**
did	0.5451 ***	0.1505
	(0.1419)	(0.1670)
lnedu	0.5361	−0.1971
	(0.4207)	(0.4373)
lnpopu	1.1168 *	1.3701
	(0.6286)	(1.0904)
lnrincome	−0.0046	0.4463 ***
	(0.0897)	(0.1643)
lnroad	−0.0953	0.8487
	(0.4518)	(0.5852)

Table 6. *Cont.*

	(1)	(2)
	Rich in Collective Forests	**Poor in Collective Forests**
tem	0.3379 **	−0.5678
	(0.1397)	(0.3881)
lngrain	−0.1686	−0.3796
	(0.1975)	(0.4086)
lnwages	0.8121	−0.5021
	(0.5243)	(0.7507)
lnaccum	0.0078	−0.0011
	(0.0073)	(0.0107)
_cons	−13.9763 ***	−3.4263
	(4.9127)	(11.6891)
Province FE	Y	Y
Year FE	Y	Y
N	294	294
adj. R2	0.8572	0.8265

Note: ***, **, and * are significant at the 1%, 5%, and 10% statistical levels, with standard errors in parentheses.

Table 6 reveals that in provinces rich in collective forest resources the CFTR has a significant positive impact on the production of commercial timber. There was a 54.51% increase in commercial timber production, far exceeding the 24.18% from the baseline regression. However, in provinces with less abundant collective forest resources this figure is only 15.05%, and the impact is not significant. This indicates that in provinces with more collective forest resources the CFTR has facilitated an increase in the production of commercial timber. This also corroborates the robustness of the results from the baseline regression, which showed that the CFTR increased the production of commercial timber. This confirms Hypothesis 1.

5. Empirical Results for Non-Commercial Timber Production

5.1. Baseline Regression

The baseline regression results examining the impact of the CFTR on non-commercial timber production are shown in Table 7. From column (1), without the inclusion of control variables, the CFTR's impact on non-commercial timber production is significantly positive at the 10% significance level. In column (2), which includes control variables, this impact remains significantly positive at the 5% significance level. Column (4) presents the regression results after excluding data from 2008 and including control variables, where the coefficient for the CFTR variable remains significantly positive. Despite a year-on-year decline in non-commercial timber production, the regression results still indicate that the CFTR has led to an increase in non-commercial timber production. The implementation of the CFTR has resulted in a 34.37% increase in non-commercial timber production in the affected provinces. An explanation for this is that the CFTR granted farmers more complete property rights, increasing their demand for non-commercial timber for purposes like building houses, renovations, and firewood. This validates Hypothesis 3.

Table 7. Baseline regression results for non-commercial timber production.

	(1)	(2)	(3)	(4)
	Full Sample	**Full Sample**	**Excluding 2008**	**Excluding 2008**
did	0.3063 *	0.3437 **	0.2446	0.2811 *
	(0.1594)	(0.1563)	(0.1589)	(0.1527)
lnedu		−0.0759		−0.1864
		(0.4973)		(0.5321)
lnpopu		−0.5757		−0.6770
		(0.4809)		(0.4940)
lnrincome		−0.3811 ***		−0.3641 ***
		(0.1347)		(0.1370)
tem		0.0179 **		0.0165 **
		(0.0073)		(0.0072)
lnsquare		0.0427		0.0618
		(0.0636)		(0.0657)
lnelectric		−0.7993 **		−0.7980 **
		(0.3574)		(0.3624)
lnroad		−0.1049		−0.1202
		(0.1177)		(0.1202)
_cons	2.8780 ***	14.5879 ***	2.9075 ***	15.6525 ***
	(0.1237)	(4.7862)	(0.1220)	(4.9337)
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	448	448	420	420
adj. R2	0.8928	0.8963	0.8903	0.8938

Note: ***, **, and * are significant at the 1%, 5%, and 10% statistical levels, with standard errors in parentheses.

5.2. Parallel Trend Test and Dynamic Effects Analysis

The parallel trend test and dynamic effects analysis for the CFTR's impact on non-commercial timber production were conducted using the year before policy implementation as the baseline, as shown in Figure 5. The results reveal that, before the CFTR, the regression coefficients for the CFTR variable were statistically insignificant, indicating that provinces in both the treatment and control groups shared similar trends in non-commercial timber production before the implementation of the CFTR. This outcome confirms that the parallel trend assumption is met. This demonstrates that our baseline regression results are robust.

The dynamic characteristics of the CFTR's impact on non-commercial timber production are analyzed based on Figure 5. It is observed that a significant increase in non-commercial timber production occurred in the first year following the CFTR. Comparatively, the significant increase in commercial timber production only manifested in the second year after the CFTR. This aligns with the fact that, after the CFTR, the harvesting of non-commercial timber did not require government approval, whereas commercial timber harvesting still needed governmental clearance, a process often involving procedural delays. From the second year after the CFTR, the positive effect of the CFTR on non-commercial timber production persisted but was no longer statistically significant. This suggests that after the CFTR farmers increased their non-commercial timber production to meet their production and living needs, but once these needs were satisfied they did not further increase their non-commercial timber production. This trend indicates that while the CFTR initially boosted non-commercial timber production the long-term effect on increasing such production was not pronounced, thus validating Hypothesis 3.

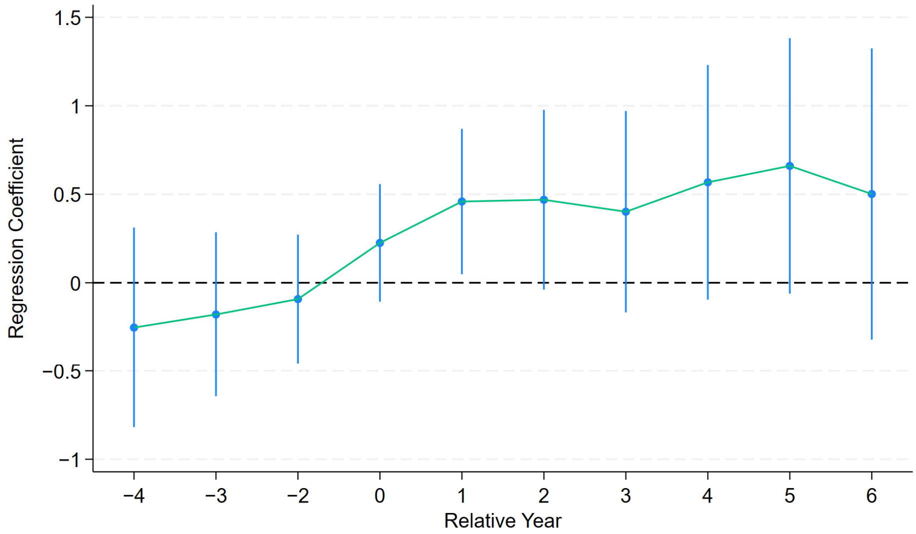

Figure 5. Parallel trends test and dynamic effect analysis for non-commercial timber production. Note: the dots represent regression coefficients, and the vertical lines represent the 95% confidence intervals.

5.3. Robustness Tests

The robustness of the findings regarding the impact of the CFTR on non-commercial timber production was tested using a placebo approach, like the method described in Section 4.3.1. The probability density graph of the regression coefficients of the did variable from 1000 regressions is shown in Figure 6. The vertical dashed line on the right side of the graph represents the regression coefficient of the did variable from the baseline regression. The figure reveals that the coefficients from the randomly assigned regressions are concentrated near zero, with a mean of 0.0166 and an estimated standard deviation of 0.05. In contrast, the regression coefficient of the did variable in the baseline regression, 0.3437, is far from this mean. This result indicates that arbitrarily setting the timing and province of the CFTR does not significantly affect the production of non-commercial timber. Conversely, it confirms that the actual implementation of the CFTR has indeed increased the production of non-commercial timber.

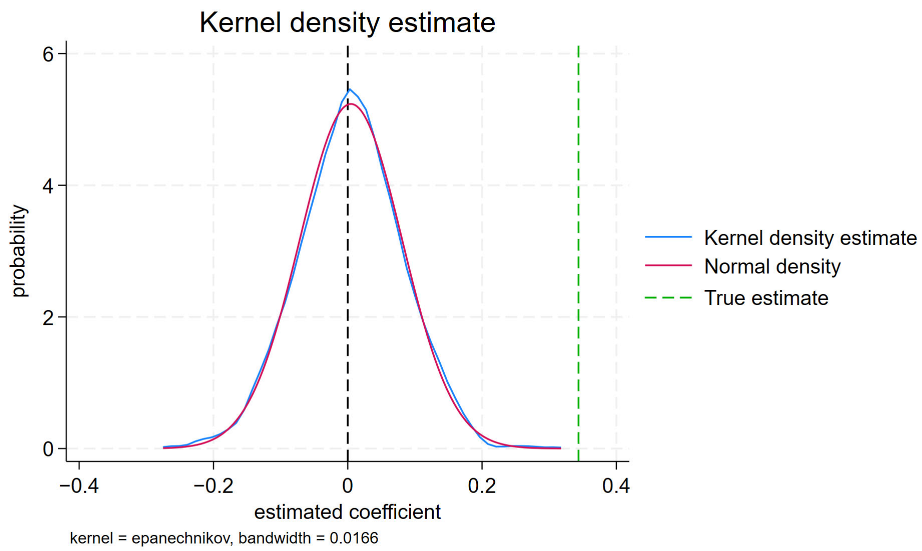

Figure 6. Results of the placebo test for non-commercial timber production.

6. Mechanism Analysis

Through the above analysis, the CFTR has significantly increased both commercial and non-commercial timber production. This section delves deeper into understanding the mechanisms behind this impact. The analysis begins by examining the mechanism of "CFTR—Forest Land Structure Adjustment—Increase in Commercial Timber Production". It then assesses the role of timber market prices in enhancing the production effect of the CFTR.

6.1. Mediating Analysis for Commercial Timber Production

Based on Equation (4) for mediation effects analysis, with the results presented in column (2) of Table 8, column (1) shows the baseline regression results. As seen in column (2) of Table 8, the effect of the CFTR on forest land structure adjustment is significantly positive at the 5% level. This indicates that the CFTR significantly increased the proportion of economic forests. Before the CFTR, collective forests were uniformly managed by collectives, which had weaker incentives to convert timber forests into economic forests. After the CFTR, individual farmers managed collective forests, gaining greater autonomy in forestry production. Farmers adjusted their forest land structure based on their resource endowments and market conditions. They tended to produce economic forests with shorter production cycles and better economic benefits, thereby increasing the proportion of economic forests. This implies a reduction in timber forest area and an increase in commercial timber production in the short term. The results indicate that following the CFTR farmers converted timber forests to economic forests, increasing the output of commercial timber. This is in line with Hypothesis 2.

Table 8. Mediating analysis regression results for commercial timber production.

	(1)	**(2)**
	Commercial Timber Production	**Structure**
did	0.2418 **	91.7785 **
	(0.1111)	(39.3913)
lnedu	0.0816	-2.1×10^2
	(0.3391)	(137.5184)
lnpopu	1.0848 **	543.2952 ***
	(0.5436)	(130.6474)
lnrincome	0.2445 ***	−41.4567
	(0.0890)	(30.5081)
lnroad	−0.0033	−17.4370
	(0.1371)	(43.6311)
tem	0.0020	4.3638 *
	(0.0067)	(2.2676)
lngrain	−0.1559	-2.2×10^2 **
	(0.1927)	(111.7719)
lnwages	0.2042	556.3159 ***
	(0.4770)	(196.7777)
lnaccum	0.7363 *	122.7108
	(0.3855)	(150.6147)
_cons	−10.4961 **	-7.7×10^3 ***
	(4.8264)	(1.9×10^3)

Table 8. *Cont.*

	(1)	(2)
	Commercial Timber Production	**Structure**
Province FE	Y	Y
Year FE	Y	Y
N	588	504
adj. R2	0.8649	0.5305

Note: ***, **, and * are significant at the 1%, 5%, and 10% statistical levels, with standard errors in parentheses.

Having confirmed that the CFTR led to an increase in the proportion of economic forests, the analysis also considers other factors contributing to this increase. The following question then arises: how does the CFTR affect commercial timber production after excluding the factor of forest land structure adjustment? To answer this, the study includes the forest land structure adjustment variable as a control in the dynamic effects model based on Equation (2) (with the year prior to policy implementation as the base period) to examine how the CFTR affects the production of commercial timber after excluding the factors of forest land structure adjustment. Using the results presented in Figure 7, it shows that after excluding the forest land structure adjustment variable the impact of the CFTR on commercial timber production still follows an initial increase followed by a decrease. In the second to fourth years after CFTR implementation, commercial timber production significantly increased, but by the fifth year the production-enhancing effect of the CFTR was no longer significant. Comparatively, without controlling for forest land structure adjustment, the CFTR had a significant production-enhancing effect on commercial timber from the second to sixth years post-implementation, with a higher significance than after controlling for forest land structure adjustment. The weakening of the CFTR's production-enhancing effect on commercial timber after excluding the forest land structure adjustment factor further illustrates that part of the CFTR's impact on increasing commercial timber production was realized through forest land structure adjustment. These results validate Hypothesis 2.

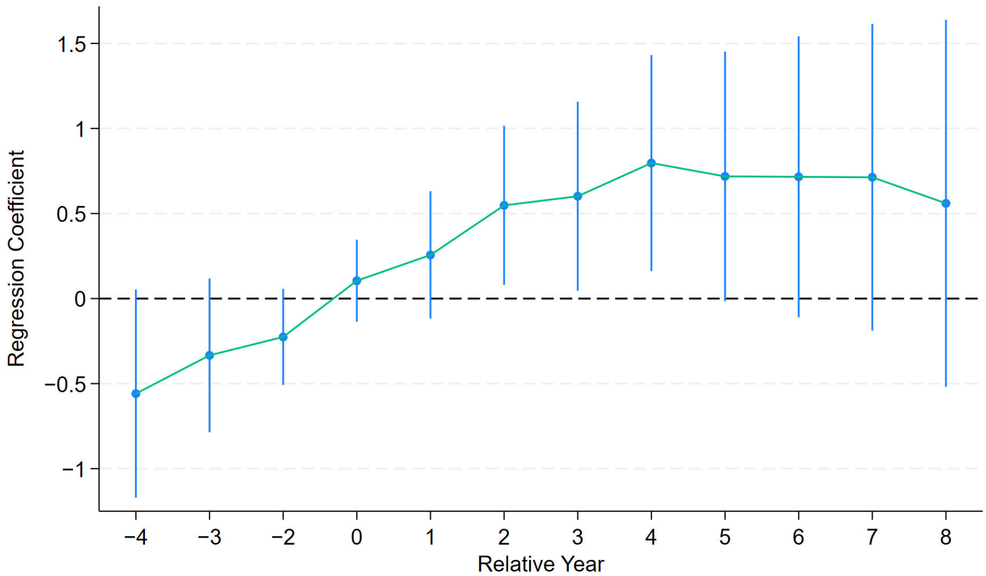

Figure 7. Dynamic effects after excluding the mediating effect of forest structure. Note: the dots represent regression coefficients, and the vertical lines represent the 95% confidence intervals.

6.2. Wood Market Prices Analysis for Both Productions

The baseline regression results have already indicated that the CFTR can increase the production of both commercial and non-commercial timber. However, there is a significant variation in timber prices across provinces in China. Based on this observation, this section analyzes whether the price level of timber has a varying impact on the effectiveness of the CFTR policy. Specifically, this involves using the annual average timber sales prices (in CNY) of each province from 2003 to 2018. Each year, the provinces are ranked based on their timber prices, and these annual rankings are then summed up. Based on the aggregated results, provinces are divided into two groups: those with higher prices and those with lower prices. This approach is used to explore the impact of the CFTR policy on timber production under different price levels, providing more insights for micro-adjustments in forestry policy.

Table 9 presents the regression analysis results of commercial timber production based on timber price grouping. Columns (1) and (2) reflect the baseline regression results for high-priced areas, while columns (3) and (4) represent the results for low-priced areas. The model includes fixed effects for province (Province FE) and year (Year FE) to control for unobserved heterogeneity across provinces and over time. Table 9 shows that in provinces with high timber prices the CFTR has a significant positive impact, increasing commercial timber production by approximately 52.35%, compared to 24.18% in the baseline regression. In provinces with less abundant collective forest resources this effect is significantly reduced and not statistically significant. This indicates that the CFTR has promoted an increase in the production of commercial timber in provinces with higher wood prices, but the impact is not significant in areas with lower wood prices. These results confirm Hypothesis 4.

Table 9. Baseline regression results for commercial timber production stratified by price.

	(1)	(2)	(3)	(4)
	High-Price Regions	**High-Price Regions**	**Low-Price Regions**	**Low-Price Regions**
did	0.5828 ***	0.5235 ***	0.0844	0.0411
	(0.1173)	(0.1445)	(0.1783)	(0.1827)
lnedu		0.3534		0.1632
		(0.4131)		(0.8258)
lnpopu		−1.5520 **		1.9963 ***
		(0.6263)		(0.7673)
lnrincome		0.2465 **		0.2857 **
		(0.1105)		(0.1412)
lnroad		−0.9758 **		0.6695
		(0.4559)		(0.6118)
tem		0.2528 *		−0.2504
		(0.1290)		(0.2316)
lngrain		0.6525 **		−0.2844
		(0.2616)		(0.3222)
lnwages		−0.1818		−0.0823
		(0.5305)		(0.6658)
lnaccum		0.0001		−0.0004
		(0.0072)		(0.0127)
_cons	4.1689 ***	13.1129 **	3.4449 ***	−12.7238
	(0.0810)	(5.7716)	(0.1068)	(8.8025)

Table 9. *Cont.*

	(1)	(2)	(3)	(4)
	High-Price Regions	**High-Price Regions**	**Low-Price Regions**	**Low-Price Regions**
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	294	294	252	252
adj. R2	0.7554	0.7673	0.8250	0.8358

Note: ***, **, and * are significant at the 1%, 5%, and 10% statistical levels, with standard errors in parentheses.

Similar to Table 9, Table 10 shows the regression analysis results for non-commercial timber production based on timber price grouping. According to the hypothesis of this paper, when timber market prices are high farmers tend to increase the production of commercial timber and decrease the production of non-commercial timber, converting it to commercial timber for higher economic benefits. The baseline regression shows that the CFTR can significantly increase the production of non-commercial timber. Therefore, it is expected that in areas with high timber prices the impact of the CFTR on increasing non-commercial timber production would be weaker, as indicated by smaller coefficients in columns (1) and (2) compared to (3) and (4). However, the results show that in areas with high timber prices, the reform actually has a stronger effect on increasing non-commercial timber production. In areas with low timber prices, the CFTR seems to have no impact on non-commercial timber production. A possible reason is that in China the harvesting of commercial timber must adhere to strict quotas [2], while non-commercial timber harvesting is not regulated by the government. Therefore, in areas with high timber prices, farmers might harvest under the guise of non-commercial timber and sell it in the market. However, this portion, which is actually used as commercial timber, is recorded as non-commercial timber, resulting in a stronger observed impact of the reform on non-commercial timber production in high-price areas.

Table 10. Baseline regression results for non-commercial timber production stratified by price.

	(1)	(2)	(3)	(4)
	High-Price Regions	**High-Price Regions**	**Low-Price Regions**	**Low-Price Regions**
did	0.2030	0.4899 **	−0.1259	−0.0328
	(0.1802)	(0.2010)	(0.1772)	(0.1687)
lnedu		−0.1725		−0.1640
		(0.4418)		(0.7258)
lnpopu		1.2141 *		−1.7463 ***
		(0.6843)		(0.4842)
lnrincome		−0.2765 ***		−0.5627 ***
		(0.0897)		(0.1803)
tem		0.0197 **		0.0188 *
		(0.0086)		(0.0113)
lnsquare		−0.0897		0.1896
		(0.0821)		(0.1216)
lnelectric		1.6852 ***		−1.2370 ***
		(0.5478)		(0.3891)
lnroad		−0.0975		−0.3221 *
		(0.0693)		(0.1827)

Table 10. *Cont.*

	(1)	(2)	(3)	(4)
	High-Price Regions	**High-Price Regions**	**Low-Price Regions**	**Low-Price Regions**
_cons	3.6918 ***	−12.0762	3.0534 ***	27.7509 ***
	(0.1468)	(7.3643)	(0.1322)	(5.1744)
Province FE	Y	Y	Y	Y
Year FE	Y	Y	Y	Y
N	224	224	192	192
adj. R2	0.8585	0.8798	0.8681	0.8890

Note: ***, **, and * are significant at the 1%, 5%, and 10% statistical levels, with standard errors in parentheses.

7. Discussion

Firstly, this study uses macro-level statistical data, which effectively avoids potential biases that may arise from the use of micro-level survey data of households in previous studies. Before the CFTR, most collective forests were managed by village collectives, resulting in low timber production by farming households. However, after the CFTR, households gained collective forests, with family-based management becoming the main form of forestry operation. In other words, the CFTR significantly increased the area of forest land managed by households, naturally leading to an increase in their timber production. Therefore, analyzing the impact of the CFTR on timber production based solely on household data before and after the CFTR would be inaccurate. This study uses macro-level statistical data for analysis, specifically including timber produced by villages and lower-level organizations, as well as timber for household use and firewood, all of which correspond to the timber output from collective forests, both before and after the CFTR. Such empirical analysis better elucidates the impact of the CFTR on timber production.

Secondly, the long-term nature of the data allows for a better observation of the CFTR's long-term effect on increasing timber production. Although similar to the agricultural land tenure reform of the 1980s, the CFTR differs in its outcomes. Unlike agricultural land, which requires input for output, the CFTR not only vested the usage rights of collectively owned forest land in farmers but also transferred ownership of the trees. This incentivized farmers to sell trees for profit, leading to a short-term increase in commercial timber production. However, after the CFTR, farmer management practices diverged. While some continued to manage forests for timber, increasing long-term timber production, others converted them into economic forests or left them fallow due to low economic returns, adversely affecting long-term timber production. Although the proportion of these different practices among farmers remains uncertain, empirical results suggest that by the seventh year after the CFTR the increase in commercial timber production was negligible. This suggests significant diversification in forest management post-family takeover, with some farmers leaving land fallow due to small scale and low economic returns, reducing land productivity. Further facilitating land transfer and scale management is crucial for increasing land productivity. The "Deepening Collective Forest Tenure System Reform Plan" issued by China in September 2023 also emphasizes promoting forest land transfer and moderately scaled forestry operations, expected to enhance land productivity.

Lastly, the empirical results of this study indicate that some farmers transformed timber forests into economic forests after the CFTR, thus increasing short-term timber production. This structural adjustment, while a pursuit of higher economic returns, reduces long-term timber production and contradicts the requirements of China's Forest Law. Therefore, future measures should clarify forest land use and strengthen its regulation to ensure the area and production of timber forests. The results also show that timber market prices have a moderating effect on the timber production increase due to the CFTR, indicating farmers' sensitivity to market prices. Hence, further improvement in the timber trade market and promotion of stable price increases would motivate farmers to enhance forestry management and investment, thereby increasing land productivity and timber production.

Although this study utilizes macro-level statistical data to effectively avoid potential biases present in previous studies that used micro-surveys of households, it may not capture all the details at the micro-level survey data. For instance, it cannot identify changes in farmers' inputs in forestry production. Additionally, due to data availability, this research uses data from 1998–2018. While this covers a long period, it lacks the most recent years' data. After 2018, there were significant changes in China's economic environment and further development in CFTR policies, such as advancing collective forest turnover and promoting large-scale operations, all of which could impact timber production. Therefore, our data might not fully reflect the latest impact of the policies. However, this study addresses the deficiencies in previous research regarding data and empirical analysis of long-term dynamic changes in timber production, offering a new perspective on the analysis of the CFTR and providing a significant supplement to the existing literature. Based on the findings of this study, future research can update the data and investigate the dynamic impacts of specific aspects of the CFTR, as well as how forestry should be managed for better sustainable development in the future. These insights provide valuable references for policymakers in optimizing forest tenure systems and the forestry market, to promote sustainable development and efficient management of forestry.

8. Conclusions

This study focuses on the impact of the CFTR on timber production, using panel data from 28 provinces across China from 1998 to 2018 to construct a Time-varying Difference-in-Differences (DID) model. The research examines how the CFTR influences both commercial and non-commercial timber production. It further explores the mechanisms of land structure and the impacts of collective forest resource abundance and timber prices under forest reform, thereby elucidating the mechanisms through which forest rights reform affects timber production.

The key findings are as follows. The CFTR has a significantly positive effect on both commercial and non-commercial timber production, with the CFTR leading to a 24.18% increase in commercial timber production and a 34.37% increase in non-commercial timber production. The CFTR initially boosts timber production in the short term, but this effect diminishes over time. The impact on commercial timber production varies with the abundance of collective forest land resources; in areas with richer resources, the production increased by 54.51%, while there was no significant effect in less resource-rich areas. The CFTR leads to a structural adjustment of forest land, with an increasing proportion of economic forests, thereby boosting commercial timber production in the short term. Finally, in regions with higher timber market prices, the CFTR's effect on increasing commercial timber production is more significant. Based on these conclusions, the following countermeasures are proposed:

Promote scaled forestry operations: The findings indicate that the impact of the CFTR on increasing timber production diminishes over time, sometimes even turning negative. Issues such as small-scale forest lands, high labor costs, and low forestry operation benefits suggest that small-scale forestry is not suitable for China's current economic stage. Therefore, it is advised to guide farmers to transfer forest land management rights through renting, shareholding, and co-operation. Support farmers in combining forces in various forms for production, promoting family joint operations, co-operative operations between rural collective economic organizations and farmers, and entrusted management models for farmers. This would facilitate an organic connection between small-scale farmers and modern forestry development.

Optimize timber harvesting control systems: Currently, most governments in China implement strict timber harvesting quota policies. While these policies are necessary for environmental protection and management, their complex application processes and high transaction costs burden farmers. To increase timber production, protect forest farmers' rights, and promote sustainable forest development, simplifying the application process and reducing transaction costs are necessary. Specific measures include streamlining the application process, introducing online application platforms, and making public the allocation of timber harvesting quota indicators. These measures can better balance ecological protection with economic development while safeguarding the interests of forest farmers.

Enhance policy subsidies: According to this paper's findings, in regions with higher market prices forest right reforms significantly enhance commercial timber production, whereas in lower-priced areas there is significant potential for increased production. Considering forests' ecological services like water and soil conservation, climate regulation has evident positive externalities; the government should provide appropriate subsidies for forestry operations in lower-priced areas. Such policies can not only help increase timber production but also promote the harmonious development of economy and ecology, effectively addressing market failures. Through this approach, more comprehensive and sustainable utilization and protection of forestry resources can be achieved.

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