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Ecological-economic trade-offs in forest conservation: China's public welfare forest compensation policy on farmers' production factor reallocation and livelihood diversification

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Introduction: China's public welfare forest compensation policy is a pivotal environmental governance tool, promoting ecological conservation and advancing the practice of Payments for Environmental Services (PES). While prior studies have primarily focused on short-term ecological or income outcomes, there remains a lack of research on the policy's long-term influence on rural households' production factor allocation and livelihood strategies across forestry, agriculture, and non-agricultural sectors.

Methods: This study employs panel data from 12,810 farming households in 18 counties across 9 provinces, spanning the years 2003 and 2007–2019. A differences-in-differences (DID) model is applied to evaluate the impact of the compensation policy on rural production behaviors, including inputs in forestry, planting, animal husbandry, and labor allocation.

Results: The analysis reveals that the policy significantly reduces input use in forestry, especially among more actively participating households. It moderately increases non-agricultural labor supply—mainly through labor out-migration—but shows no significant impact on planting or animal husbandry. Although the policy supports under-forest economic activities, it fails to fully compensate for declines in inputs to bamboo, economic, and timber forests. Policy effects vary significantly across different household types, shaped by resource endowments and regional economic contexts.

Discussion: These findings provide robust, long-term empirical evidence on the production-side effects of ecological compensation. The study highlights the importance of designing more nuanced PES policies that account for household heterogeneity and regional disparities, aiming for greater equity and effectiveness in implementation.

KEYWORDS

compensation policy for public welfare forests, production factors input, production structure, policy effect, differences-in-differences method

1 Introduction

Ecosystems around the world are under unprecedented pressure due to population growth and rapid economic development. Environmental issues such as deforestation, biodiversity loss, water scarcity, and climate change have become global challenges and seriously threaten human survival and development (Arora and Melton, 2018). The international community has explored a number of environmental governance strategies in an effort to address related issues, and it generally recognizes the significance of preserving ecosystem services. Among them, Payments for Environmental Services, an innovative ecological protection mechanism, has received widespread attention and practice around the world (Feng et al., 2018; Wang et at., 2024b). Payments for Environmental Services encourage individuals, communities, and governments to participate in ecological protection through economic incentives, aiming to coordinate and balance ecological environmental protection and economic development.

China, the largest developing country in the world and an essential participant in the construction of ecological civilization, is also facing severe environmental problems (Hansen and Umbreit, 2018). Despite its impressive economic progress since the reform and opening up in 1978 (Liu and Diamond, 2005; Wang et al., 2007; Mullan et al., 2011), China still has noteworthy environmental issues. In particular, driven by factors such as rapid population expansion and poor ecological and environmental management, China's terrestrial ecosystems suffered tremendous damage in the second half of the last century, which was mainly manifested in the depletion of forest resources, the vicious circle of the grassland system, and the decline in the productivity of forested land in rural areas (Yin, 2009; Liu et al., 2015; Liu and Wang, 2019; Wang et al., 2019). These challenges not only cause the soil erosion, biodiversity loss, greenhouse gas emissions and other related environmental problems, but also adversely affect the production and life of rural residents, such as the reduction of forestry output, the increase of unemployment rate and the instability of income (Xu et al., 2006; Uchida et al., 2007). To tackle these challenges, our government has been implementing relevant major ecological restoration and construction plans since this century, including forest ecological compensation, natural forest protection projects and returning farmland to forests projects (Wang et al., 2007; Yin, 2009; Liu et al., 2013).

As an essential aspect of Payments for Environmental Services in China, ecological compensation for public welfare forests has emerged as the major component for preserving natural ecosystems and advancing sustainable development. To address environmental challenges, the Chinese government has aggressively adopted a series of ecological restoration and construction plans (Gómez-Baggethun et al., 2010; Fisher et al., 2009). The compensation policy for public welfare forests is a vital part of China's forest ecological compensation program (Liu and Zhang, 2019; Nian et al., 2025), which maintains forest coverage and improves forest quality by strictly prohibiting commercial logging, nurturing and renovation activities. Furthermore, other forestry management activities or the development of non-timber resources using under-forest resources are restricted by various conditions. Additionally, in the process of implementing the compensation policy for public forests, the government compensates farmers for a certain amount of production losses. The compensation policy for public welfare forests is a type of ecological benefit compensation policy, similar to a series of ecological protection and restoration projects, such as returning farmland to forests and preserving natural forests (Zhang et al., 2018; Dai et al., 2009). Due to its substantial public financial investment, comprehensive geographical coverage (29 provinces and autonomous regions), and rural household participation, this is the largest ecosystem service compensation project in China and other developing countries (Liu and Zhang, 2019). In addition to improving China's environmental situation in water conservation, wind and sand fixation, soil and water conservation, disaster prevention and mitigation, this policy and other ecosystem service compensation projects can also bring benefits to other countries in the world in mitigating climate change and maintaining biodiversity (Yin, 2009; Daily and Matson, 2008).

Measuring the significance of compensation policy for public welfare forests concentrates on considering its efficacy in achieving multiple objectives (Parris et al., 2003), with criteria mainly reflected in the impact on the ecological and economic activities. The former is mainly manifested in the function and stability of ecosystems, such as controlling soil erosion, preserving forest resources, restoring biodiversity and carbon storage (Sánchez-Azofeifa et al., 2007; Arriagada et al., 2009; Costedoat et al., 2015; Chu et al., 2019), which have been widely discussed in related literature (Jumbe and Angelsen, 2006; Brouwer et al., 2011). However, the environmental benefits take time. There are specific "spillover effects" and "time-delay" (Johannes et al., 2019; Pattanayak et al., 2010), which are mainly attributed to the complexity of the interaction between the socioeconomic system and the ecological environment during the implementation of the project, making it difficult to isolate the ecological effects completely (Adhikari and Boag, 2013; Pagiola et al., 2002). At the level of economic activities, the compensation policy for public welfare forests reflects its influence by inducing social and economic changes (Yin, 2009; Ostrom, 2007), and its main task is to redistribute the land, capital, and labor employment structure of rural families (Xu et al., 2004; Gauvin et al., 2010).

This study focuses on the impact of compensation policy for public welfare forests on the importance of economic activities (production factors allocation). To evaluate the immediate effects of policies on the regional socio-economy or socio-ecology, existing research primarily concentrates on short-term household survey data (Wang et al., 2007; Liu et al., 2008; Yin and Yin, 2010). The development of the rural family economy can be accelerated by reallocating ecological compensation projects and optimizing production factor resources by changing the production structure of forestry, planting, animal husbandry, non-agricultural employment, etc. (Liao et al., 2019). Specifically, the compensation policy for public welfare forests may lead to a fundamental change in the traditional mode of production, such as reducing the capital and labor input of forestland and prompting farmers to turn to the under-forest economic model so as to absorb the surplus factors of production. This initial stage of transformation may temporarily inhibit the economic growth of forest areas (Liao et al., 2019; Wang et al., 2024a,b). Simultaneously, farmers may transfer resources and labor from forestry to other industries, especially non-agricultural employment, due to policy incentives. However, its effectiveness depends on the initial human and material capital conditions (Uchida et al., 2009). However, the specific impact of policies on planting, animal husbandry and non-agricultural employment varies greatly (Yao et al., 2010). Wang et al. (2019) found that the compensation policy for public welfare forests has a direct impact on farmers' planting decision-making. Farmers typically decide to boost planting income by raising the input of production factors for planting or even farther flowing into cultivated land, since higher public welfare forest subsidy income tends to reduce the likelihood of land abandonment. The reason is that farmers living in remote areas have relatively higher forestland resources endowments so that they can enjoy relatively more compensation income from public welfare forests. However, these farmers often have something in common to a certain extent: their living standards are relatively low, and their means of making a living are relatively single. Although they generally cannot engage in timber management to protect forest resources, the compensation income from public welfare forests has become an essential channel for their livelihood. On this basis, farmers who receive relatively higher compensation income from public welfare forests can use compensation income for planting investment, such as purchasing pesticides, fertilizers and planting equipment, thus increasing planting income (Zhang et al., 2019; Shu and Yue, 2017). Similarly, the compensation policy for public welfare forests can also accelerate the transfer of labor force to non-agricultural sectors, triggering the increase of non-agricultural activities (Yin et al., 2014). And the compensation policy for public welfare forests needs to meet some preconditions, such as popularizing skills training, improving human capital, improving the non-agricultural employment market, etc., and the policy effect under the difference of time and space can be different (Liu and Lan, 2015; Xiong and Li, 2017; Song et al., 2018). However, some relevant literature shows that the compensation policy for public welfare forests has no impact or even a negative impact on the increase of production factors of the planting industry or has no impact on the change of non-agricultural employment (Zhang et al., 2018; Zhang et al., 2019).

Although the existing studies have revealed many profound insights, they all have certain limitations in data, that is, the sample size is too small or the data period is insufficient. Specifically, some studies are based on the data set containing only 350 households covering three time points in 1999, 2002, and 2004 (Uchida et al., 2007), while others are based on 600 households covering two time points in 1999 and 2006 (Yao et al., 2010). Others rely on data from 929 households only at a single time point in 2007 (Li et al., 2011). Due to the lack of long-term, continuous and broad geographical survey data of farmers, although the compensation policy for public welfare forests has been implemented for more than 10 years, many problems have not been effectively solved. What is the actual impact of public welfare compensation policy on local forestry, planting, animal husbandry, non-agricultural production and other livelihood methods? Can government subsidies encourage farmers to increase forestry investment or turn to other industries? These issues have yet to reach a consensus in academic circles. These issues have to be resolved because they have a direct bearing on how well Payments for Environmental Services work and how future ecological restoration and conservation policies are developed in China and even the world (Tallis et al., 2008).

The purpose of this study is to systematically evaluate the impact of compensation policy for public welfare forests on farmers' production factors allocation by using large-scale survey data covering 9 provinces (autonomous regions) and 18 counties across the country, covering a total of 12,810 farmers' samples from 2003, 2007 to 2019. After being verified by strict parallel trend tests and other econometric methods, the differences-in-differences model is used for empirical analysis. The academic contribution margins of this study include: (1) analysis of long-term effect. Unlike most studies focusing on short-term effects (Yin and Yin, 2010; Yao et al., 2010; Rodriguez et al., 2015), this study covers up to 14 years after implementing the compensation policy for public welfare forests, thus enabling a more comprehensive assessment of its long-term effects. (2) Rigorousness of methodology. Although it has become a trend in academic circles to choose differences-in-differences models to identify cause and effect (Uchida et al., 2007; Groom et al., 2010), it is challenging to ensure parallel trends between the experimental and control groups before policy implementation by using short-term data, affecting unbiased results. This study can rigorously examine and validate the consistency of medium and long-term trends and improve the reliability of the result by utilizing long-term data. (3) Expansion of research perspective. Currently, the research on compensation policy for public welfare forests primarily focuses on the compensation principle (Noordwijk and Leimona, 2010), public welfare forest compensation mechanism (Li G. et al., 2020; Li J. et al., 2020), public welfare forest compensation method (Wang et al., 2016), public welfare forest compensation standard (Mutandwa et al., 2019), farmers' willingness to participate in compensation policy for public welfare forests (Guo et al., 2015), the income effect of compensation policy for public welfare forests, etc. (Li G. et al., 2020; Li J. et al., 2020), but there is not much discussion about how this regulation impacts farmers' production factors input. This study fills this academic gap and provides a new perspective for a deeper insight into the comprehensive impact of compensation policy for public welfare forests.

The central research question this paper addresses is: As a crucial component of China's payment for ecosystem services (PES) system, how does the ecological compensation policy for public welfare forests achieve the dual objectives of ecological conservation and economic development by restructuring rural households' allocation of production factors? Based on the world's largest ecosystem compensation program implemented across 29 provincial-level administrative regions in China, this study systematically examines the long-term impact mechanisms of this policy on farmers' production behaviors, with particular focus on three key issues: Does the policy effectively guide farmers to transition from traditional forestry production to sustainable management models? How does compensation funding influence different livelihood strategies by altering capital and labor input structures? What differentiated characteristics emerge in policy effects under heterogeneous conditions? The answers to these questions will not only evaluate the effectiveness of PES mechanisms in China but also provide policy references for developing countries worldwide seeking to balance ecological protection with rural development.

The structure of this paper is organized as follows: Section 2 begins by detailing the data sources and research methodology used in this study, emphasizing the econometric models and variables selected to assess the impact of the ecological compensation policy for public welfare forests. It also explains the rationale for using the differences-in-differences model to address the research questions. Section 3 presents the empirical results, focusing on the effects of the compensation policy on various aspects of farmers' production factors allocation, including labor and capital inputs. The section also discusses the results of robustness checks and their implications for the reliability of the findings. Section 4 interprets these empirical results within the context of the theoretical framework introduced in Section 1, linking the findings to existing literature on Payments for Environmental Services (PES) and rural development. This section also explores the heterogeneous effects of the policy across different farmer groups, regions, and levels of participation, providing a nuanced understanding of how ecological compensation can be leveraged for both environmental and economic goals. Finally, Section 5 concludes the paper by summarizing the key findings, discussing their policy implications for China's ecological compensation system, and suggesting directions for future research that could help optimize the policy's impact on rural livelihoods and ecological sustainability (Figure 1).

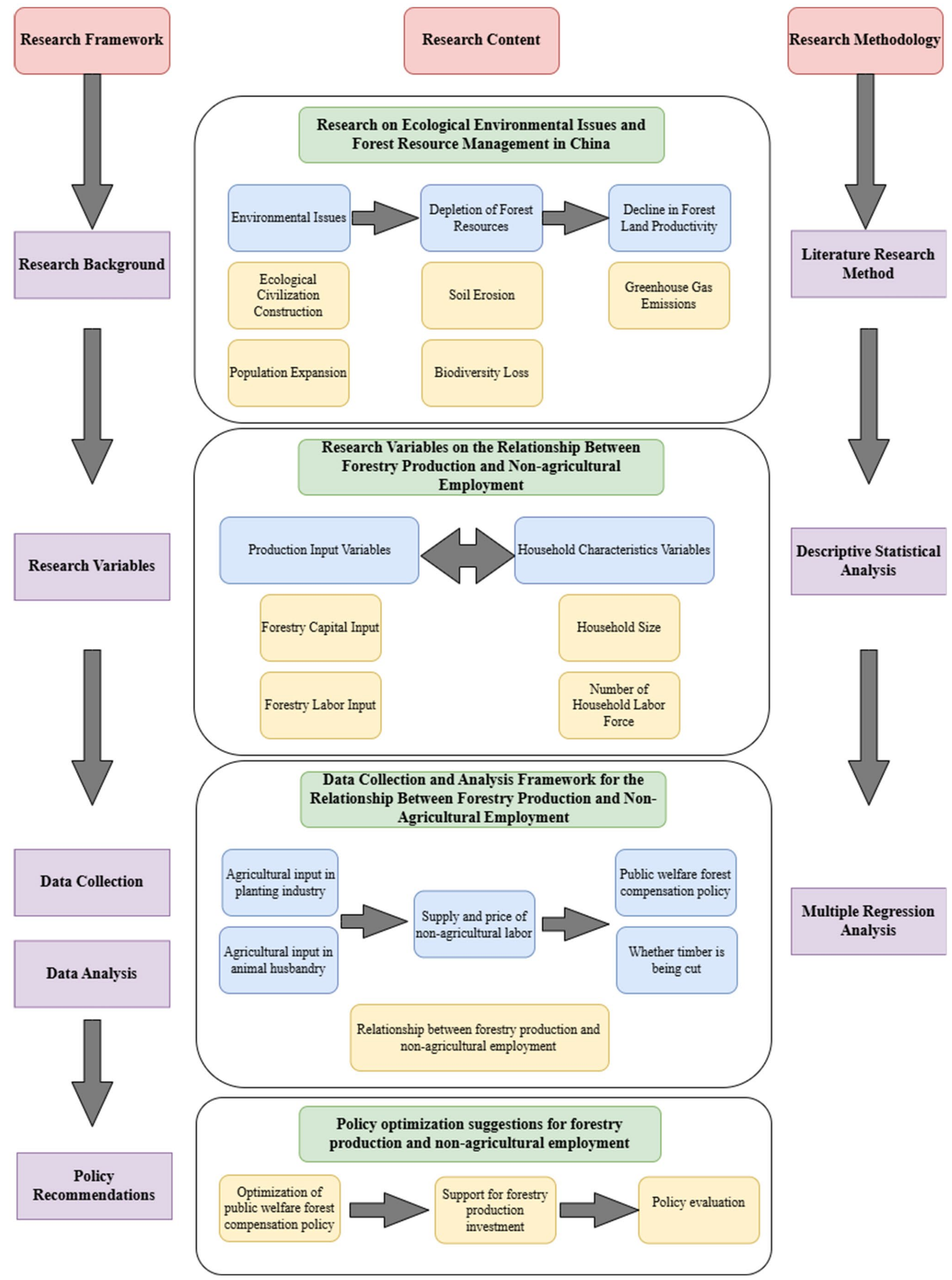

FIGURE 1
Technical route.

2 Data and methods

2.1 Data sources

The data of this study are derived from the farmer survey database of the Development Research Center of the State Forestry and Grassland Administration. Stratified random sampling technology was use to collect the data and information of farmers' families. The sample provinces autonomous region and sample counties are determined by comprehensively considering the social and economic development level, regional distribution characteristics, natural resources conditions and public welfare forest construction. Nine provinces (autonomous region), including Liaoning, Shandong, Henan, Sichuan, Guangxi, Jiangxi, Hunan, Zhejiang and Fujian, were selected as sample provinces (autonomous region), which included the eastern, central, western, northeastern, northern and southern parts of China. Therefore, our sample is appropriate as a case for implementing compensation policy for public welfare forests. Each province (autonomous region) selects 2 counties, for a total of 18 counties. Excluding samples with incomplete observation time points and inconsistent questionnaire information, we finally established a unique survey data covering 12,810 farmer samples from 2003, 2007, and 2019. The data of linked variables are transformed into constant prices in 1994 using the rural consumer price index and the rural means of production price index.

2.2 Variable selection

First, the dependent variables. Based on the studies by Wen et al. (2023), Hu et al. (2019), and Yang et al. (2024), the dependent variables in this study are defined as forestry production input, planting production input, animal husbandry production input, and non-agricultural labor supply. These variables reflect the reallocation of farmers' production factors across different sectors. Specifically, forestry production input includes both capital and labor dedicated to forestry activities; planting production input comprises capital and labor invested in crop cultivation; and animal husbandry production input consists of capital and labor allocated to livestock operations. The supply of non-agricultural labor is measured by the labor input of farmers engaged in off-farm employment. To address the issue of high variance in production factor inputs across the sample, all dependent variables are logarithmically transformed.

Second, core independent variable. Following the approach of previous studies such as Benye et al. (2023) and Shang et al. (2018), the core independent variable in this study is whether farmers participate in the compensation policy for public welfare forests. Farmers are considered participants if their public welfare forest area is greater than zero or if they receive subsidy income from the policy. Once a farmer is identified as a participant in a given year, they are treated as participants in subsequent years as well, consistent with the cumulative and sustained nature of policy exposure. Accordingly, a binary variable is constructed: participating farmers are assigned a value of 1, while non-participating farmers are assigned a value of 0.

Third, control variables. Considering other factors that may affect farmers' input of production factors, this study summarizes the control variables into three dimensions: Firstly, market characteristic variables, including non-agricultural labor price and timber price indicators. Secondly, the characteristic variables of farmers include the age, gender, health status, educational background of the person in charge of household, whether the head of household is a cadre, the number of the household population, the number of the household labor force, whether to cut timber, whether to engage in forestry production and whether it is non-agricultural employment indicators; Thirdly, resource characteristic variables. Including forestland area, bamboo forest area proportion, economic forest area proportion and timber forest area proportion. It is worth noting that if the control variable is a dummy variable, the original assignment have to be maintained; Otherwise, logarithmic processing will be adopted. The descriptive statistics of the variables involved in this study are shown in Table 1.

2.3 Empirical method

The intuitive method to evaluate the impact of compensation policy for public welfare forests on farmers' input of production factors is to compare the differences between whether they participate in compensation policy for public welfare forests. However, this difference is not only affected by whether farmers participate in the compensation policy for public welfare forests but also by other control variables or unobservable factors. As a commonly used policy evaluation tool, the differences-in-differences model (Difference-in-Differences, DID) has significant advantages in eliminating the interference of other simultaneous factors. The basic idea of this model is to construct two groups: farmers affected by the policy (experimental group) and farmers unaffected by the policy (control group). By comparing the relative changes in production factor input between these two groups before and after the implementation of the policy, the actual effect of the policy can be evaluated more accurately. Specifically, the differences-in-differences model utilizes the change of production factors input of farmers in the control group as the benchmark, which reflects the natural change trend under the action of all other factors, excluding the influence of the compensation policy for public welfare forests. Subtracting the corresponding changes of farmers in the control group from the changes of production components input of farmers in the experimental group allows us to calculate the net effect of the compensation policy for public welfare forests. This method framework effectively controls endogenous problems such as reverse causality and missing variables, thus improving the accuracy and reliability of the explanation of policy implementation effects.

In this study, the differences-in-differences model was used to estimate the impact of compensation policy for public welfare forests on farmers' input of production factors, the specific formula is as Equation 1 follows.

$$Y_{it} = \beta_0 + \beta_1 treat_i * post_t + \beta_2 X_{it} + \mu_i + \varepsilon_{it} \tag{1}$$

In the formula: i is the ith individual farmer, t is the year, Y_{it} represents the input of production factors by farmer i in year t, X_{it} denotes a control variable vector, ì$_i$ denotes a time-fixed effect, å$_{it}$ is a random perturbation term. $treat_i$ indicates whether farmers participate in the compensation policy for public welfare forests, and if they have participated, then $treat_i$= 1, otherwise $treat_i$=0. $post_t$ represents a dummy variable of time. If the time is after participating

TABLE 1 Variable description and descriptive statistics.

Variable	Variable description	Average	Standard deviation
Capital investment in forestry	Capital investment for forestry production/yuan	622.6112	3045.001
Labor input in forestry	Labor input/person-day for forestry production	31.9945	65.6863
Capital investment in planting industry	Capital investment for planting production/yuan	941.9011	2298.56
Labor input in planting industry	Labor input/person-day for planting production	61.5505	77.3956
Capital investment in animal husbandry	Capital investment for animal husbandry production/yuan	1438.165	9545.994
Labor input in animal husbandry	Labor input/person-day for livestock production	39.5416	81.1932
Non-agricultural labor supply	Labor input/person-day for non-agriculture employment	243.7765	265.1281
Compensation policy for public welfare forests	Yes = 1; No = 0	0.3102	0.4626
Non-agricultural labor prices	Unit: Yuan/person-day	53.7979	21.6467
Timber price	Unit: yuan/cubic meter	444.1625	89.6522
Age	Unit: year	52.2335	10.8194
Gender	Male = 1; Female = 0	0.9712	0.1673
Educational background	Unit: Year	7.3218	2.8699
Health status	Health = 1; Unhealthy = 0	0.8961	0.3052
Whether the person in charge of household is a cadre	Yes = 1; No = 0	0.2478	0.4317
Number of household population	Unit: Person	3.9644	1.5116
Number of household labor	Unit: Person	2.7275	1.2289
Whether to cut timber	Yes = 1; No = 0	0.0417	0.1999
Whether to participate in forestry production	Yes = 1; No = 0	0.6293	0.483
Whether to participate in non-agriculture employment	Yes = 1; No = 0	0.7205	0.4488
Woodland area	Unit: mu	45.7088	77.6761
Proportion of bamboo forest area	Proportion of bamboo forest area to total forest area/%	0.0668	0.2194
Proportion of economic forest area	Proportion of economic forest area to total forestland area/%	0.0805	0.2395
Proportion of timber forest area	Proportion of timber forest area to total forestland area/%	0.5913	0.4467

in the compensation policy for public welfare forests, then $post_t = 1$. Coefficient $\hat{a}_1$ indicates the effect of compensation policy for public welfare forests.

3 Empirical results and analysis

3.1 Benchmark regression results

The benchmark regression results of how farmers' production factors input is impacted by the compensation policy for public welfare forests are shown in Table 2. The results show that the compensation policy has a significant positive impact on farmers' forestry production factors input and non-agricultural labor supply but has no pronounced effect on planting and animal husbandry production factors input. Obviously, due to its stringent restrictions on forestry production and management, the compensation policy for public welfare forests leads to the decline of forestland that farmers can control independently, which naturally leads to a decrease in the input of forestry production factors. However, the substitution effect of production factors of compensation policy for public welfare forests mainly applies to replacing forestry with non-agricultural employment. This is generally consistent with the view that the forest ecological compensation policy mainly affects the non-agricultural employment of rural households through the simple substitution effect of production factors put forward by Uchida et al. (2007) and Kelly and Huo (2013). However, although the compensation policy of the public welfare forests positively impacts the input of production factors in planting and animal husbandry, it is not significant. The relative substitution elasticity of the industrial linkage effect partly explains the reason. Due to the long periodicity of forestry production, the average value of the input of forestry production factors is relatively small after the whole forestry production cycle is equally shared. Because of the relatively flexible employment characteristics of non-agricultural activities, it is easier to absorb the input of forestry production factors that are forced to be "squeezed out," so the relative substitution elasticity of forestry production and non-agricultural employment is large. However, farmers engaged in planting production find it difficult to attract or stimulate the enthusiasm of increasing the input of production factors in planting because of their relatively fixed land resource endowments and low-level surplus of means of production, so the relative substitution elasticity of forestry and planting is small; For animal husbandry, farmers engaged in animal husbandry production need farmland to provide food for livestock (Alary et al., 2011), so the relative fixation of planting production will naturally not cause drastic fluctuations in animal husbandry production.

TABLE 2 Benchmark regression results.

Variable	Forestry		Planting		Animal husbandry		Non-agricultural labor supply
	Capital	Workforce	Capital	Workforce	Capital	Workforce	
Compensation policy for public welfare forests	−0.0322** (0.0136)	−0.0687*** (0.0248)	0.0251 (0.0160)	0.0506 (0.0310)	0.0147 (0.0163)	0.0582 (0.0450)	0.0498*** (0.0192)
Non-agricultural labor prices	−0.0006 (0.0004)	−0.0030*** (0.0004)	−0.0050*** (0.0003)	−0.0030 (0.0019)	−0.0007*** (0.0002)	−0.0021** (0.0010)	0.0026*** (0.0003)
Timber price	0.0001*** (0.0000)	0.0006*** (0.0001)	−0.0002** (0.0001)	−0.0003 (0.0002)	−0.0000 (0.0001)	−0.0000 (0.0003)	−0.0002** (0.0001)
Age	−0.0011** (0.0005)	−0.0007 (0.0010)	−0.0011* (0.0006)	−0.0043*** (0.0010)	−0.0002 (0.0003)	−0.0027* (0.0015)	−0.0005 (0.0007)
Gender	0.0680*** (0.0257)	0.1663*** (0.0517)	0.1391*** (0.0333)	0.0343 (0.0437)	0.0499** (0.0221)	0.1286 (0.1855)	0.2366*** (0.0399)
Educational background	−0.0012 (0.0013)	−0.0082** (0.0032)	−0.0009 (0.0021)	−0.0011 (0.0036)	−0.0018** (0.0008)	−0.0017 (0.0051)	0.0249*** (0.0025)
Health status	0.0396* (0.0227)	0.2387*** (0.0351)	0.1207*** (0.0226)	0.1512*** (0.0393)	0.0041 (0.0101)	0.1780*** (0.0512)	0.2372*** (0.0271)
Whether the person in charge of household is a cadre	0.0079 (0.0076)	0.0098 (0.0206)	−0.0107 (0.0133)	0.0590** (0.0248)	0.0237*** (0.0062)	0.1191*** (0.0321)	0.0082 (0.0159)
Number of household population	0.0032 (0.0037)	0.0136* (0.0080)	0.0106** (0.0052)	0.0376*** (0.0084)	−0.0015 (0.0023)	0.0265* (0.0143)	0.0560*** (0.0062)
Number of household labor	0.0014 (0.0050)	0.0126 (0.0106)	0.0296*** (0.0068)	0.0211* (0.0113)	0.0049* (0.0027)	0.0462*** (0.0174)	0.1436*** (0.0082)
Whether to cut timber	0.0083 (0.0235)	0.2032*** (0.0446)	−0.0323 (0.0288)	−0.0661 (0.0717)	0.0290 (0.0192)	0.0420 (0.0724)	−0.1605*** (0.0345)
Whether to participate in forestry production	0.0574*** (0.0096)	12.5967*** (0.0181)	−0.0739*** (0.0117)	−0.0485** (0.0193)	−0.0123** (0.0053)	−0.1472*** (0.0322)	−0.0397*** (0.0140)
Whether to participate in non-agriculture employment	−0.0095 (0.0072)	−0.2166*** (0.0201)	−0.0309** (0.0129)	−0.0012 (0.0210)	−0.0074 (0.0056)	−0.1292*** (0.0384)	14.6610*** (0.0155)
Woodland area	0.0003*** (0.0001)	0.0018*** (0.0001)	−0.0003*** (0.0001)	−0.0002 (0.0002)	−0.0001** (0.0001)	−0.0005*** (0.0002)	−0.0001 (0.0001)
Proportion of bamboo forest area	0.0726* (0.0378)	0.0818* (0.0468)	−0.1468*** (0.0302)	−1.8599 (2.4317)	0.0151 (0.0133)	−0.0878 (0.0632)	−0.1016*** (0.0362)
Proportion of economic forest area	0.0241* (0.0145)	0.6099*** (0.0433)	−0.0480* (0.0279)	−0.0958 (0.0737)	−0.0099 (0.0166)	−0.1593 (0.1237)	−0.0060 (0.0335)
Proportion of timber forest area	−0.0036 (0.0132)	−0.0323 (0.0282)	−0.0380** (0.0182)	−0.0036 (0.0315)	−0.0093 (0.0126)	−0.0278 (0.0496)	−0.0171 (0.0218)
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control
Constant term	0.0555 (0.0557)	−9.4995*** (0.0994)	0.1443** (0.0641)	−0.1767* (0.0997)	0.0519 (0.0410)	−0.9046*** (0.2429)	−9.7251*** (0.0768)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.357	0.280	0.061	0.056	0.062	0.086	0.290

*Represents that the estimated coefficient of the variable is significant at the 10% statistical level; ** represents significant at the 5% statistical level; *** represents significant at the 1% statistical level. The table below is the same.

3.2 Robustness test

In order to strengthen the robustness of the regression results of the model, the correlation robustness test is carried out. First, taking the proportion of public welfare forests in the county as the characterization variable of compensation policy for public welfare forests, this method can effectively prevent the self-selection tendency that may occur when implementing compensation policy for public welfare forests. The results in Table 3 show that the compensation policy of the public welfare forest still significantly impacts farmers' forestry production factor input and non-agricultural labor supply. However, it still has no pronounced effect on planting and animal husbandry production factor input, and the regression results are relatively stable. Second, the input variables of production factors are

TABLE 3 Robustness test.

Variable	Forestry		Planting		Animal husbandry		Non-agricultural labor supply
	Capital	Workforce	Capital	Workforce	Capital	Workforce	
Replace core variables							
Compensation policy for public welfare forests	−0.0308* (0.0182)	−0.0723*** (0.0138)	0.0220 (0.1290)	0.0880 (0.3512)	0.0161 (0.0114)	0.0576 (0.0419)	0.0387*** (0.0074)
Control variable	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.1154*** (0.0147)	−9.5097*** (0.1433)	0.0931 (0.0920)	0.3290 (0.2703)	−0.1120*** (0.0193)	−0.1669** (0.0822)	−9.6801*** (0.1650)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.174	0.285	0.063	0.045	0.091	0.124	0.292
Tobit model							
Compensation policy for public welfare forests	−0.0325*** (0.0046)	−0.0821* (0.0439)	0.0068 (0.0362)	0.0334 (0.0219)	0.0179 (0.0153)	0.0401 (0.0517)	0.0740** (0.0297)
Control variable	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.0781*** (0.0182)	−9.0072*** (0.1608)	0.0241 (0.1416)	0.0006 (0.0840)	0.0084 (0.0207)	−0.0047 (0.1841)	−9.3199*** (0.1296)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.311	0.279	0.052	0.028	0.116	0.189	0.291
Eliminate relevant policy interference							
Compensation policy for public welfare forests	−0.0207* (0.0112)	−0.0475* (0.0255)	0.0174 (0.0165)	0.0473 (0.0311)	0.0122 (0.0164)	0.0380 (0.0490)	0.0454* (0.0260)
Control variable	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.1294*** (0.0381)	−9.5008*** (0.1008)	0.0959 (0.0652)	−0.1909* (0.1080)	0.0084 (0.0458)	−1.3217*** (0.2866)	−9.5962*** (0.0949)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.502	0.280	0.065	0.059	0.069	0.041	0.290

continuous and have the data structure characteristics of censoring on the left side of 0. Referring to the research of Angrist and Pischke (2009), the Tobit method is also an appropriate approach. The results show that the Tobit model still does not significantly change the estimation results of the benchmark regression model. Third, in promoting the compensation policy of the public welfare forest, the related forestry policies that affect farmers' production and business activities also cross-run simultaneously, which may lead to potential bias in the benchmark regression results. Therefore, under the interference of policies such as controlling the new round of collective forest tenure system reform, forest insurance system, logging quota management system, participation in forestry professional cooperative organizations and forestry subsidies, although the economic significance has declined, the impact of compensation policy for public welfare forests on farmers' production factors input is still roughly the same as the benchmark regression result. It should be noted that only the input of forestry production factors and non-agricultural labor supply will be tested and empirically analyzed, as the benchmark regression results and robustness test show no discernible effect of the compensation policy for public welfare forests on the input of production factors of planting and animal husbandry.

3.3 Parallel trend test

Given that there may be provinces, cities, counties or villages that do not choose to implement compensation policy for public welfare forests based on the principle of randomness, this will violate the common trend hypothesis conditions, so it is necessary to test the parallel trend hypothesis before using the differences-in-differences model. That is, it is assumed that there is generally the same long-term trend between participating farmers and non-participating farmers (Lin and Wu, 2015). More specifically, without the intervention of compensation policy for public welfare forests, the trend of production factors input for participants and non-participants should be roughly the same. However, if this assumption does not hold in the differences-in-differences model, it can cause severe internal effects. Therefore, this study employs two approaches to ensure the parallel trend assumption. First, this study draws on the approach of Li et al. (2016) and adds the interaction term of village characteristic variables and time variables based on the benchmark model, and eliminates the non-parallel trend that may exist in the experimental group and the control group due to the change of time trend of village characteristics by controlling the time trend of different village characteristics. The results in Table 4 show that the compensation policy of the public welfare forests still significantly impacts farmers' input in forestry production factors and non-agricultural labor supply. Second, this study draws on the approach of Moser and Voena (2012), and adds the interaction terms of regional fixed effects and time variables on the basis of the benchmark model. The results show that the significant impact of compensation policy for public welfare forests on farmers' forestry production factors input and non-agricultural labor supply is still robust.

3.4 Placebo test

To verify whether the benchmark regression results are disturbed by other unobservable factors, this study draws on the approach of Cai et al. (2016). It randomly assigns the implementation year of the "virtual" compensation policy for public welfare forests to sample farmers and then conduct a placebo test. Specifically, any year from 2003 to 2019 was randomly selected as the implementation year of the compensation policy for public welfare forests, and 500 differences-in-differences estimates were made. In this process, the randomly generated estimation coefficient of the compensation policy for public welfare forests in the experimental group should not significantly reject zero. Otherwise, it indicates a bias in the setting of the benchmark model. Figure 2 shows the distribution of coefficients of the placebo test. The results showed that the estimated coefficients of compensation policy for public welfare forests under placebo test were mainly distributed near 0 points, indicating that the randomly generated "virtual experimental group" did not produce significant policy effect. Most of the p-values corresponding to the estimated coefficients were more significant than 0.1, which rejected the null hypothesis that there was no difference between the estimated results of the placebo test and the actual estimated results, indicating that the benchmark regression results had strong robustness.

3.5 Impact of compensation policy for public welfare forests on farmers' forestry production structure

To deeply analyze the impact of compensation policy for public welfare forests on farmers' input on forestry production factors, Table 5 reports the impact of compensation policy for public welfare forests on farmers' input on forestry production factors under different forestry production structures. The results show that the compensation policy for public welfare forests significantly impacts farmers' under-forest economic capital and labor input. However, it significantly reduces the capital and labor input of bamboo, economic, and timber forests. Combined with the results in Table 2, it can be seen that the reduction effects of compensation policy for public welfare forests on farmers' forestry capital and labor force are 0.0322 and 0.0687, respectively, while the incremental effects on farmers' under-forest economic capital and labor force are 0.0121 and 0.0103. Obviously, the reduction effect of the compensation policy for public welfare forests on the forestry capital and labor of the farmers completely hides its incremental effect on the capital and labor of the under-forestry economy, and the reduction effect mainly stems from the reduction of capital and labor inputs in bamboo forests, economic forests and timber forests caused by the compensation policy for public welfare forests, which is attributed to the ban on timber forests and stringent management restrictions on the production and management of bamboo forests and economic forests implemented by the compensation policy for public welfare forests.

3.6 Impact of compensation policy for public welfare forests on farmers' production factors input with different participation degrees

Given the influence of compensation policy for public welfare forests on farmers' forestry production factors input, it is necessary to explore whether this effect is affected by other factors to clarify the boundary conditions of this effect. For farmers with different participation degrees, there may exist apparent differences in the impact of compensation policy for public welfare forests on their input in forestry production

TABLE 4 **Parallel trend test.**

Variable	Temporal trend of controlled village characteristics			Temporal trend of controlled area characteristics		
	Forestry capital	Forestry labor force	Non-agricultural labor supply	Forestry capital	Forestry labor force	Non-agricultural labor supply
Compensation policy for public welfare forests	−0.0146*** (0.0039)	−0.1165* (0.0692)	0.0291*** (0.0063)	−0.0050** (0.0025)	−0.0133* (0.0080)	0.0554* (0.0306)
Control variable	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control
Constant term	−0.1193*** (0.0088)	−9.3967*** (0.2297)	−9.6958*** (0.1439)	0.0411 (0.0358)	−9.6718*** (1.0032)	−10.4228*** (0.2353)
Observations	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.231	0.282	0.290	0.294	0.282	0.288

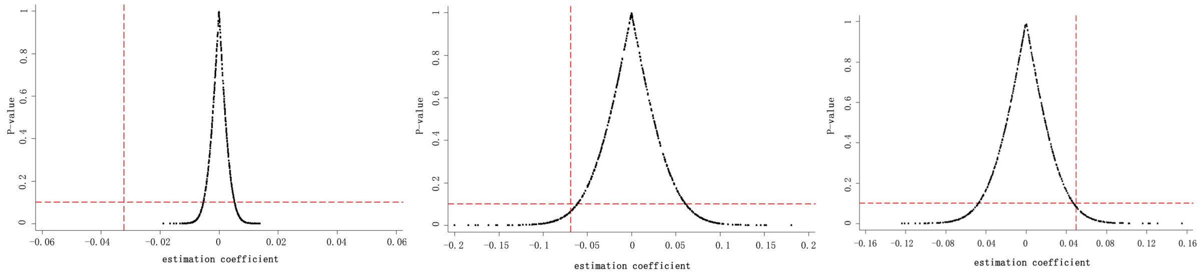

FIGURE 2
Placebo test.

TABLE 5 Impact of compensation policy for public welfare forests on farmers' forestry production structure.

Variable	Bamboo forest		Economic forest		Timber forest		Under-forest economy	
	Capital	Workforce	Capital	Workforce	Capital	Workforce	Capital	Workforce
Compensation policy for public welfare forests	−0.0280* (0.0146)	−0.0156*** (0.0051)	−0.0283*** (0.0049)	−0.0237** (0.0119)	−0.0321*** (0.0119)	−0.0287*** (0.0102)	0.0121* (0.0068)	0.0103* (0.0062)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.1212* (0.0635)	−9.3700*** (0.1865)	−0.0593** (0.0282)	−9.4803*** (0.4124)	0.0105 (0.0536)	−9.7476*** (0.3097)	−0.0548 (0.0369)	−9.2108*** (0.2417)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.275	0.282	0.168	0.282	0.354	0.283	0.293	0.277

factors. The impact of the compensation policy for public welfare forests on farmers' input of forestry production factors with different participation degrees is displayed in Table 6, which shows that the compensation policy of the public welfare forests negatively impacts the input of farmers' forestry production factors. With the increase in participation in the compensation policy for public welfare forests, this negative impact shows an increasing trend, especially in the lower-middle, middle, upper-middle and higher-participation farmers. However, there has yet to be a pronounced policy effect on the low-participation farmers. One possible explanation is that the higher degree of participation of farmers, the more pronounced the stringent management restriction of compensation policy for public welfare forests can restrict the input of forestry production factors. The compensation policy of the public welfare forest has no pronounced policy effect on farmers' input of forestry production factors with less than 25% participation degree is comparatively unaffected by low participation levels. Intensive management to increase forestry output and obtain compensation for public welfare forests can make up for the negative impact of compensation policy for public welfare forests on farmers with low participation degree to a certain extent. The compensation policy for public welfare forests makes it difficult to change their forestry dependence degree or forestry production enthusiasm.

Furthermore, from the perspective of forestry production structure, is there any significant difference in the impact of compensation policy for public welfare forests on farmers' input of forestry production factors with different degrees of participation? It should be pointed out that, no regardless of the proportion of bamboo forest, economic forest and timber forest in all farmers' forestland is, with the increase of the proportion of public welfare forest in farmers' forestland area, the areas of bamboo forest, economic forest and timber forest in public welfare forest tend to show the same direction growth trend. From the perspective of bamboo forest management, Table 7 findings indicate that, particularly for farmers with upper-middle and higher participation degrees, the effect of the compensation policy for public welfare forests on farmers' input of bamboo forest production factors first exhibits a trend of decreasing and then rising with the increase in the policy's degree of participation. The compensation policy for public welfare forests has a significant positive impact on their input of bamboo forest production factors, which sharply contrasts with the negative impact on farmers with lower-middle and middle participation degrees. According to economic forest management, the negative impact of compensation policy for public welfare forests on farmers' input of economic forest production factors is increasing with the increase of participation in compensation policy for public welfare forests. From the perspective of timber forest management, the negative impact of compensation policy for public welfare forests on farmers' input of timber forest production factors is increasing with the increase of participation in compensation policy for public welfare forests. From the perspective of under-forest economic management, the positive impact of compensation policy for public welfare forests on farmers' input of under-forest economic production factors is increasing with participation in compensation policy for public welfare forests.

In conclusion, the compensation policy for public welfare forests under different forestry production structures shows heterogeneous policy effect on farmers' production factors input with different participation degrees. This is mainly due to the gap between opportunity cost and actual income of public welfare forests of different forest types. Although the cost of managing bamboo forests is minimal, the opportunity cost of bamboo forests is the lowest due to the long-term market prices depression for bamboo timber. Even if the renewability of bamboo forests is strong, the relatively low public welfare forest compensation and limited bamboo production income obtained from bamboo forests cannot smooth the loss of normal bamboo management income for farmers with lower middle and middle participation. In contrast, the relatively high public welfare forest compensation and management income obtained from bamboo forests may equal or even exceed the income generated by normal bamboo management. Therefore, the influence of compensation policy for public welfare forests on farmers' bamboo production factors shows a U-shaped distribution from negative to positive with the improvement of farmers' participation. As far as the economic forest is concerned, the opportunity cost of economic forest in public welfare forests is relatively high due to the restriction of strict logging and other forest management activities. Even if a certain amount of public welfare forest compensation is given, the actual income of normal economic forest management is seriously lowered. As far as timber forest is concerned, due to the strict logging ban policy, the market value of timber forests cannot be realized, and the compensation given to public welfare forests is far from making up for the loss of timber forest income. Therefore, the opportunity cost of timber forests is the highest among public welfare forests. As the under-forest economic area grows, it is reasonable to assume that farmers derive their under-forest economic activities from public welfare forests. In that case, there is no doubt that farmers' input of under-forest economic production factors will increase.

3.7 Impact of compensation policy for public welfare forests on farmers' non-agricultural employment structure

To conduct an in-depth analysis of the effects of the compensation policy for public welfare forests on farmers' non-agricultural labor supply, Table 8 presents the effects of the policy under various non-agricultural employment arrangement types. The results show that the compensation policy for public welfare forests has a significant positive impact on farmers' non-agricultural labor supply and non-agricultural management labor supply, how farmers' original forestry production mode has evolved since the public welfare forest compensation policy was put into place, that is, forestry labor time has been reduced or the demand of forestry labor force has been reduced, and they can choose to reallocate labor resources in the form of non-agricultural labor or non-agricultural management through "saving labor and effort." However, transfer space often differs due to the initiative and regional dispersion of labor transfer (Tan et al., 2019). Will the spatial heterogeneity of labor transfer cause the incremental effect of compensation policy for public welfare forests on non-agricultural labor supply to be non-homogeneous? The results show that the compensation policy of the public welfare forest has a significant positive impact on the non-agricultural labor supply of farmers in different places. However, it has no pronounced effect on the local non-agricultural labor supply. It can be found that the increase of non-agricultural labor supply in different places is the primary source of the incremental effect of non-agricultural labor supply in compensation policy for public welfare forests.

3.8 Heterogeneity analysis

3.8.1 Impact of compensation policy for public welfare forests classified by forestland resource endowments

Sample farmers were divided into three groups based on the area of their forestland in order to examine the variations in the compensation policy effect of public welfare forests among various forestland resource endowments. The results in Table 9 show that the compensation policy for public welfare forests has a significant negative impact on the input of forestry production factors of farmers with medium and large forestland areas and a significant positive impact on the supply of non-agricultural labor but has no pronounced impact on the forestry production and non-agricultural employment behavior of farmers with small forestland area. This could be because farmers are more sensitive to the public welfare forest compensation policy and it is easier to influence their production decision-making behavior when natural resource endowment is larger. In other words, farmers who own small-scale forestland have comparatively poor natural resource endowments. Their decision-making preferences for forestry production and non-farm employment behaviors remain largely unchanged whether or not they engage in the public welfare forest compensation policy; however, the effects on medium and large-scale forest land area farmers are completely different.

3.8.2 Impact of compensation policy for public welfare forests classified by economic development level

Given the uneven spatial distribution of economic development levels among regions in China, we divided the sample farmers into two groups according to their location: the eastern region and the mid-western regions. The results in Table 10 show that the compensation policy of the public welfare forest significantly impacts the input of forestry production factors and non-agricultural labor supply of farmers in the mid-western regions but has no pronounced effect on farmers in the eastern regions. The possible reason lies in the differences between the two regions' levels of marketization and economic development, which result in varying degrees of reliance on forestry and, in turn, in the accessibility of non-farming jobs. These variations ultimately have a substantial impact on how the public welfare forest compensation policy affects the two farms.

3.8.3 Impact of compensation policy for public welfare forests classified by human capital endowments

We divided the sample farmers into three groups according to the labor force size to explore the changes in the effect of compensation policy for public welfare forests in different labor groups. For these three groups, the results in Table 11 show that the compensation policy for public welfare forests has a significant impact on farmers' forestry production factor input and non-agricultural labor supply, and with the improvement of human capital endowments, the impact of the compensation policy for public welfare forests is more significant. One possible explanation is that farmers tend to be more capable and rational in completing the exchange and allocation of production elements between forestry output and non-agricultural employment in a lower-cost combination if they have more endowments in human capital.

TABLE 6 Impact of compensation policy for public welfare forests on farmers' production factors input with different participation degrees.

Variable	Participation degree of compensation policy for public welfare forests: The proportion of public welfare forest in total forestland of farmers (%)									
	Proportion < 25		25 ≤ Proportion < 50		50 ≤ Proportion < 75		75 ≤ Proportion < 100		Proportion = 100	
	Capital	Workforce	Capital	Workforce	Capital	Workforce	Capital	Workforce	Capital	Workforce
Compensation policy for public welfare forests	−0.0029	−0.0199	−0.0109**	−0.0518*	−0.0126*	−0.0663**	−0.0178***	−0.0687***	−0.0322**	−0.0776***
	(0.0028)	(0.0982)	(0.0044)	(0.0310)	(0.0065)	(0.0264)	(0.0060)	(0.0248)	(0.0136)	(0.0257)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.1240***	−9.0994***	−0.0922***	−9.4439***	−0.0387	−9.5232***	−0.0615*	−9.4995***	0.0555	−9.4980***
	(0.0099)	(0.3799)	(0.0179)	(0.1321)	(0.0346)	(0.1101)	(0.0330)	(0.0994)	(0.0557)	(0.1075)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.225	0.280	0.218	0.282	0.263	0.280	0.261	0.280	0.357	0.279

3.8.4 Impact of compensation policy for public welfare forests classified by income

We divided the sample farmers into three groups according to their total household income. The results in Table 12 show that the compensation policy for public welfare forests has a significant impact on the input of forestry production factors and non-agricultural labor supply of middle and low-income farmers, but has no pronounced effect on high-income farmers. The possible reason is that the abundance of material capital affects the enthusiasm of responding to the compensation policy for public welfare forests. That is, high-income farmers are less restricted by public welfare forest compensation policy because they have comparatively more material capital and more livelihood choices, giving them greater freedom to alter household livelihood plans. However, the material capital and social capital of middle and low-income farmers are relatively weak, and the dependence on forestry is relatively high. Therefore, the income increase through non-agricultural employment is relatively constrained by land resources, so they are more sensitive to the compensation policy for public welfare forests.

4 Conclusion and discussion

Based on a large-scale, nationally representative social survey of 12,810 rural households from 18 counties across 9 provinces in China (2003, 2007–2019), this study offers a novel contribution by systematically examining how Payments for Environmental Services (PES)—specifically, the public welfare forest compensation policy—influence farmers' production factor reallocation and livelihood strategies across sectors. Unlike previous research that often focuses on short-term ecological or income effects, this study uniquely analyzes long-term, cross-sectoral behavioral adjustments in forestry, planting, animal husbandry, and non-agricultural employment. The findings reveal several innovative insights regarding policy-induced labor migration, sectoral substitution, and heterogeneity across farmer types. Specifically, this study found that:

First, the public welfare forest policy significantly negatively impacts farmers' input of forestry production factors. This result echoes the research conclusions of Liao et al. (2019). Further analysis shows that this negative impact is only significantly reflected in increasing the non-agricultural labor supply of farmers in the industrial linkage effect but has no significant impact on the input of production factors in planting and animal husbandry. This shows that the policy makers have achieved some success in realizing the ecological goals of the compensation policy for public welfare forests, and that after the forestland has been classified as public welfare forests, the farmers' inputs of forestry production factors have shown a decreasing trend, and the growth of the forestland in a near-natural state has been promoted. However, concerning farmers' economic interests, reducing input from forestry production factors may adversely affect farmers' forestry output and family livelihood. Nevertheless, farmers can adapt to this policy change by adjusting their livelihood strategies, and the transfer of a non-agricultural labor force has also alleviated the employment problem of a surplus

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TABLE 7 Impact of compensation policy for public welfare forests on forestry production structure of farmers with different participation degrees.

Variable	Participation degree of compensation policy for public welfare forests: the proportion of public welfare forest in total forestland of farmers (%)									
	Proportion < 25		25 ≤ Proportion < 50		50 ≤ Proportion < 75		75 ≤ Proportion < 100		Proportion = 100	
	Capital	Workforce	Capital	Workforce	Capital	Workforce	Capital	Workforce	Capital	Workforce
Input of bamboo forest production factors										
Compensation policy for public welfare forests	−0.0050 (0.0060)	−0.0135 (0.0094)	−0.0091* (0.0047)	−0.0142*** (0.0053)	−0.0150** (0.0070)	−0.0224*** (0.0074)	0.0137*** (0.0039)	0.0204*** (0.0070)	0.0232*** (0.0050)	0.0214** (0.0098)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.2017*** (0.0226)	−10.0862*** (0.2756)	−0.1222*** (0.0200)	−9.2051*** (0.3010)	−0.1572*** (0.0255)	−9.5198*** (0.3765)	−0.1665*** (0.0189)	−9.6773*** (0.2343)	−0.1042*** (0.0216)	−9.0262*** (0.4569)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.234	0.284	0.378	0.285	0.385	0.278	0.159	0.285	0.255	0.252
Input of economic forest production factors										
Compensation policy for public welfare forests	−0.0045 (0.0284)	−0.0078 (0.2976)	−0.0073* (0.0041)	−0.0101** (0.0048)	−0.0110*** (0.0042)	−0.0130* (0.0069)	−0.0145*** (0.0048)	−0.0179*** (0.0069)	−0.0206*** (0.0056)	−0.0237** (0.0119)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.0443 (0.1298)	−8.3067*** (1.3612)	−0.1483*** (0.0142)	−9.2264*** (0.1804)	−0.0993*** (0.0157)	−9.4472*** (0.3062)	−0.0984*** (0.0172)	−9.7317*** (0.2291)	−0.0362 (0.0247)	−9.4803*** (0.4124)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.182	0.255	0.300	0.278	0.191	0.271	0.296	0.286	0.216	0.282
Input of timber forest production factors										
Compensation policy for public welfare forests	−0.0021 (0.0223)	−0.0118 (0.0187)	−0.0091* (0.0051)	−0.0204* (0.0107)	−0.0125** (0.0055)	−0.0212** (0.0107)	−0.0194*** (0.0058)	−0.0213** (0.0106)	−0.0280*** (0.0052)	−0.0237** (0.0110)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	0.0802 (0.1642)	−9.3006*** (0.7613)	−0.1615*** (0.0166)	−9.2272*** (0.6379)	−0.1372*** (0.0182)	−9.2472*** (0.6315)	−0.0176 (0.0260)	−9.3079*** (0.6215)	−0.0875*** (0.0198)	−9.4250*** (0.6471)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.366	0.272	0.234	0.278	0.420	0.278	0.220	0.278	0.258	0.279

(Continued)

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TABLE 7 (Continued)

Variable	Participation degree of compensation policy for public welfare forests: the proportion of public welfare forest in total forestland of farmers (%)									
	Proportion < 25		25 ≤ Proportion < 50		50 ≤ Proportion < 75		75 ≤ Proportion < 100		Proportion = 100	
	Capital	Workforce	Capital	Workforce	Capital	Workforce	Capital	Workforce	Capital	Workforce
Input of economic production factors under forest										
Compensation policy for public welfare forests	0.0063** (0.0032)	0.0015** (0.0006)	0.0076* (0.0039)	0.0035*** (0.0008)	0.0080** (0.0038)	0.0084* (0.0047)	0.0082** (0.0038)	0.0101*** (0.0038)	0.0146*** (0.0048)	0.0177** (0.0078)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.1129*** (0.0133)	−9.0901*** (0.2847)	−0.0474*** (0.0181)	−10.0779*** (0.2201)	−0.0441** (0.0179)	−9.5508*** (0.1686)	−0.0488*** (0.0176)	−9.5519*** (0.1774)	−0.1154*** (0.0256)	−9.0266*** (0.4142)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.169	0.283	0.207	0.285	0.208	0.286	0.207	0.279	0.283	0.279

TABLE 8 Impact of compensation policy for public welfare forests on farmers' non-agricultural employment structure.

Variable	Non-agricultural labor force	Non-agriculture operating workforce	Local			Out of town		
			Non-agricultural labor force	Non-agricultural labor force	Non-agriculture management	Non-agricultural labor force	Non-agricultural labor force	Non-agriculture management
Compensation policy for public welfare forests	0.0749** (0.0373)	0.0437* (0.0258)	0.0236 (0.0657)	0.0300 (0.0647)	0.0178 (0.0636)	0.0424** (0.0198)	0.0786* (0.0450)	0.0239*** (0.0092)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	−1.5595*** (0.1367)	−1.3030*** (0.1084)	−9.9726*** (0.2545)	−0.6716* (0.3472)	−0.6602*** (0.2464)	−11.6667*** (0.9347)	0.5391 (1.1261)	−1.5436*** (0.3125)
Observations	12,810	12,810	12,810	12,810	12,810	12,810	12,810	12,810
R^2	0.493	0.249	0.287	0.224	0.241	0.284	0.545	0.286

TABLE 9 Impact of compensation policy for public welfare forests classified by forestland resource endowments.

Variable	Small-scale woodland area			Medium-scale woodland area			Large-scale woodland area		
	Forestry capital	Forestry labor force	Non-agricultural labor supply	Forestry capital	Forestry labor force	Non-agricultural labor supply	Forestry capital	Forestry labor force	Non-agricultural labor supply
Compensation policy for public welfare forests	−0.0162 (0.0403)	−0.0103 (0.0631)	−0.0078 (0.0282)	−0.0268** (0.0104)	−0.0341*** (0.0095)	0.0279*** (0.0087)	−0.0433** (0.0178)	−0.0550** (0.0239)	0.0660*** (0.0217)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.1871** (0.0942)	−9.3861*** (0.2416)	−9.6706*** (0.1359)	0.0120 (0.0369)	−9.9364*** (0.4754)	−9.2288*** (0.3181)	−0.3843*** (0.1074)	−11.5353*** (1.4421)	−8.7341*** (0.4793)
Observations	4,270	4,270	4,270	4,270	4,270	4,270	4,270	4,270	4,270
R^2	0.146	0.285	0.289	0.368	0.271	0.288	0.523	0.278	0.294

TABLE 10 Impact of compensation policy for public welfare forests classified by economic development level.

Variable	Mid-western region			Eastern region		
	Forestry capital	Forestry labor force	Non-agricultural labor supply	Forestry capital	Forestry labor force	Non-agricultural labor supply
Compensation policy for public welfare forests	−0.0346*** (0.0052)	−0.0720** (0.0324)	0.0641** (0.0305)	−0.0164 (0.0172)	−0.0111 (0.0393)	0.0075 (0.0547)
Control variable	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control
Constant term	−0.0836*** (0.0197)	−9.3065*** (0.1185)	−9.8495*** (0.1194)	−0.2529*** (0.0433)	−9.3857*** (0.1923)	−9.2929*** (0.2956)
Observations	7,168	7,168	7,168	5,642	5,642	5,642
R^2	0.286	0.281	0.288	0.162	0.279	0.288

TABLE 11 Impact of compensation policy for public welfare forests classified by human capital endowments.

Variable	Low human capital			Middle human capital			High human capital		
	Forestry capital	Forestry labor force	Non-agricultural labor supply	Forestry capital	Forestry labor force	Non-agricultural labor supply	Forestry capital	Forestry labor force	Non-agricultural labor supply
Compensation policy for public welfare forests	−0.0094* (0.0052)	−0.0205*** (0.0050)	0.0217* (0.0110)	−0.0188* (0.0096)	−0.0546*** (0.0109)	0.0433* (0.0253)	−0.0308*** (0.0107)	−0.0732** (0.0335)	0.0729** (0.0335)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.1295*** (0.0198)	−10.0749*** (0.1816)	−10.6799*** (0.4336)	−0.0476* (0.0287)	−9.8310*** (0.4201)	−9.6873*** (0.6969)	0.0258 (0.0539)	−9.9553*** (0.7281)	−9.8501*** (0.1580)
Observations	4,270	4,270	4,270	4,270	4,270	4,270	4,270	4,270	4,270
R^2	0.200	0.285	0.287	0.466	0.269	0.288	0.244	0.285	0.288

TABLE 12 Impact of compensation policy for public welfare forests classified by income.

Variable	Low income level			Middle income level			High income level		
	Forestry capital	Forestry labor force	Non-agricultural labor supply	Forestry capital	Forestry labor force	Non-agricultural labor supply	Forestry capital	Forestry labor force	Non-agricultural labor supply
Compensation policy for public welfare forests	−0.0199*** (0.0050)	−0.0153** (0.0062)	0.0197*** (0.0044)	−0.0252** (0.0107)	−0.0353*** (0.0126)	0.0553* (0.0296)	−0.0024 (0.0038)	−0.0022 (0.0990)	−0.0235 (0.0288)
Control variable	Control	Control	Control	Control	Control	Control	Control	Control	Control
Annual fixed effect	Control	Control	Control	Control	Control	Control	Control	Control	Control
Constant term	−0.0709*** (0.0197)	−9.8597*** (0.2458)	−9.4169*** (0.1847)	−0.1754*** (0.0429)	−9.1527*** (0.5073)	−9.7604*** (0.1101)	−0.0908*** (0.0170)	−10.1576*** (0.7452)	−9.7512*** (0.1294)
Observations	4,270	4,270	4,270	4,270	4,270	4,270	4,270	4,270	4,270
R^2	0.262	0.276	0.290	0.196	0.280	0.289	0.222	0.283	0.283

labor force to a certain extent (Yin, 2009; Uchida et al., 2009), which is conducive to the protection of the ecological environment.

Second, as for the forestry production structure, the compensation policy of the public welfare forests has a significant negative impact on the input of timber forest production factors, which gradually increases with the increase of policy participation. This is mainly due to the strict ban on logging timber forests in the compensation policy for public welfare forests and the insufficient compensation standard to compensate for farmers' losses. However, the compensation policy of the public welfare forest also has a significant negative impact on the input of production factors of bamboo forest and economic forest, which is not the expected result of policymakers. The Chinese government has implemented a management restriction policy for non-timber forest species in public welfare forests. This policy stems from policymakers' concern that farmers cannot correctly manage bamboo forests and economic forests in public welfare forest areas, which may make the effect of ecological compensation policies challenging to meet the government's ecological benefit goals. However, this policy framework significantly inhibits farmers' enthusiasm for managing bamboo and economic forests. Although the follow-up policy adjustment allows under-forest management, it cannot fully compensate for the loss of all kinds of forestland. Interestingly, with the increase in policy participation, the impact of compensation policy for public welfare forests on the input of bamboo forest production factors has changed from negative to positive, which may be related to bamboo's original low market income. However, there is no similar change in the economic forest, and the negative impact of its production factor input increases with policy participation.

Third, regarding the non-agricultural production structure, the incremental effect of compensation policy for public welfare forests on farmers' non-agricultural labor supply mainly comes from non-agricultural workers and non-agricultural management labor supply. Further subdivision shows that the compensation policy for public welfare forests only has a significant positive impact on farmers' non-agricultural labor supply in different places but has not yet formed a significant effect on their local non-agricultural labor supply. This shows that the local village and provincial socioeconomic environments have a more significant impact on the supply of non-agricultural labor (Henning et al., 2013) rather than being entirely caused by the compensation policy for public welfare forests. Therefore, one of the most crucial problems that the Chinese government must address is the necessity to greatly improve the rural labor job market in order to increase the local employment market's appeal to rural excess labor.

Fourth, there are significant differences in the impact of the Yilin compensation policy on different farmer groups (Rodriguez et al., 2015; Yong et al., 2015). In this regard, we divided the sample farmers into different groups according to the regional economic development level, income, human capital and resource endowment. We found that the effects of compensation policy for public welfare forests on different groups significantly differed. Therefore, policymakers need to be aware of the role of household-level forestland resource endowments, human and physical capital endowments, and the level of regional economic development in influencing the production decisions of households through public goods forest compensation policies. Neglecting these influencing factors can become a defect in the system design of public welfare forest construction projects. Therefore, policymakers can combine the heterogeneity of farmers and regional differentiation, target the compensated subjects hierarchically, and explore differentiated compensation standards.

Fifth, with the further expansion of the public welfare forest construction scale, government-led ecological compensation is far from solving the sharp contradiction between economic development and environmental protection. The government should change its functions and roles, transition from policy leader to guide, and encourage market participants to actively participate in constructing public welfare forests. Therefore, building a public welfare forest compensation fund pool, including financial funds, social capital, and financial capital, is the key to ensuring the sustainable development of compensation policy for public welfare forests.

Future research can expand in several directions. First, the research sample can be further expanded to cover more regions and include a broader range of farmer types, thereby improving the generalizability and representativeness of the findings. Second, comparative studies can be conducted to explore the combined or differentiated effects of various ecological compensation policies (e.g., forest protection, wetland restoration) on rural production behaviors. Third, as policy implementation continues, future research could incorporate longer-term and more granular time-series data to assess the sustained ecological and socioeconomic impacts of such policies more comprehensively.

Nonetheless, this study is not without limitations. First, although it draws from a large multi-year panel dataset, the survey regions still do not cover all provinces, and certain farmer subgroups may be underrepresented. Second, while the study spans 14 years, the long-term dynamic effects of ecological compensation—especially those beyond farmers' production behavior, such as ecosystem resilience or intergenerational livelihood changes—remain to be fully captured. Third, due to reliance on self-reported data, responses may be affected by recall bias or limited understanding of policy nuances. Moreover, while the differences-in-differences model is robust, unobserved confounding factors and potential policy spillovers may introduce estimation bias. Addressing these challenges through more diverse data sources, mixed-method approaches, and structural modeling will be essential for future studies aiming to deepen policy evaluation and inform more effective compensation strategies.

5 Policy implications

First, the construction of public welfare forests should balance the economic interests of farmers with the national ecological needs, pay attention to quality rather than scale, combine the factors of land planning, economic level and natural environment, clarify the withdrawal boundary of public welfare forests, establish a dynamic adjustment mechanism and optimize the layout structure.

Second, the transformation from economic to ecological rationality depends on farmers' livelihood conversion ability. Public welfare forest compensation should positively affect farmers' livelihood, improve their ability and avoid resource loss. The compensation standard should cover the opportunity cost lost by farmers due to ecological protection.

Third, the compensation policy should consider efficiency and fairness and avoid "one size fits all." Differentiated compensation standards should be formulated to promote a win-win situation between ecology and people's livelihood according to the differences in forestland characteristics, forest species, ecological location, contribution, resource endowment, human capital, and regional economic development.

Fourth, the government should develop industries, especially rural ones, according to local resources and location advantages and promote non-agricultural employment opportunities to enhance farmers' initiative to participate in public welfare forest compensation.

Fifth, in the face of large-scale public welfare forest construction, the government should change its role from the leader to the guide, strengthen policy formulation, encourage the participation of the market, society, finance and other factors, and build a diversified compensation fund pool to ensure the sustainable development of compensation policy for public welfare forests.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

JW: Conceptualization, Software, Writing – original draft, Data curation, Formal analysis, Investigation, Methodology, Supervision. XH: Formal analysis, Software, Writing – original draft, Validation. TX: Software, Writing – original draft, Conceptualization. HL: Project administration, Resources, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

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