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ARTICLE

Economic analysis of China's grain for green policy: theory and evidence

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Abstract

First phase of the grain for green (GFG) policy, one of the China's forest policies, was implemented in the late 1990s and ended in 2012. The first phase of the GFG policy was successful from a macro perspective, although there were some failures. Based on these outcomes, the second phase of the GFG policy was implemented from 2014 to 2020. This study used panel data to develop an empirical land use model and conduct a comparative static analysis focusing on the GFG policy. Results of the static analysis confirmed factors that affect GFG for the years 2002–2018. In addition, differences in the explanatory variables between the first (2002–2012) and second periods (2014–2018) were determined. Furthermore, differences in GFG subsidies between the northern and southern provinces in the first phase were analyzed for their effects on a reforestation area. The main results revealed that the amount of investment in GFG and rural livelihood security had a positive effect on the expansion of the area of GFG. In addition, the amount of investment in GFG was more effective during the second period than the first period.

Keywords China forest conservation policy · Grain for green · GFG · Land use model · Panel data analysis

JEL Classification Q23 · Q58

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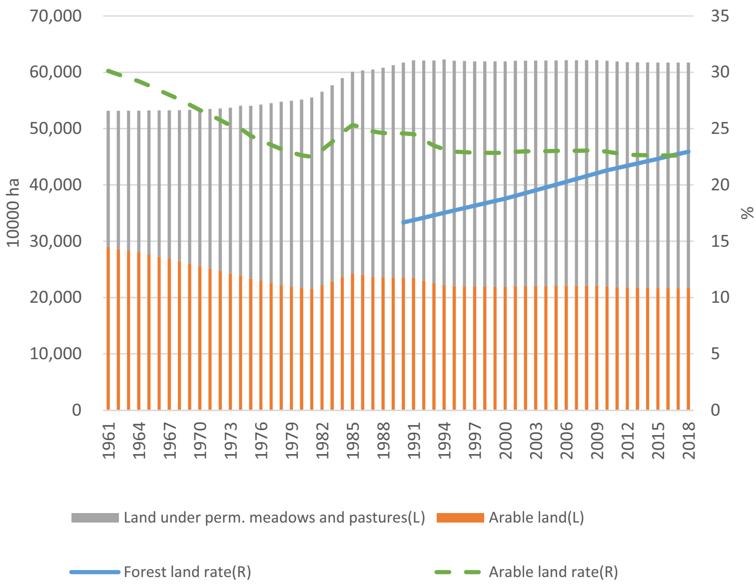


Fig. 1 Land use transition in China. Source: Compiled by the authors using FAOSTAT data

1 Introduction

Since the 1990s, the Chinese government has implemented a series of forest extension policies, because of which the ratio of forest cover has increased (Fig. 1) whereas the ratio of cultivated land has decreased. One such policy is the grain for green (GFG) policy, implemented after the *Great Flood* of 1998 by Premier Zhu Rongji for the conservation of the ecological environment.

The GFG policy aims to reforest farmland with low productivity and a weak ecological environment. Farmers who reforest their land are subsidized for their loss of livelihood. The process also creates surplus labor, and that surplus labor is transferred to other industries (Jin and Yabuta 2020). The first phase of the GFG policy was completed in 2012 (Table 1). Nonetheless, previous studies have pointed out various problems noted during the first phase of the implementation; however, owing to the shortage of labor in secondary industries in coastal areas and the shift to the production of specialty products (fruit, livestock, etc.), the GFG policy succeeded in preserving the ecological environment and increasing farmers' income, which were the original objectives of the policy. Therefore, this policy was considered successful from a macro perspective. Based on the results of the first phase, the Chinese government implemented a second phase of the GFG policy from 2014 to 2020. However, the economic development situation differed from that of the first phase. In the first phase, coastal areas experienced a shortage of labor. Moreover, minimum wages in China have since increased rapidly and there has been a shift from economic development centered on trade to expanding domestic demand.

The first phase of the policy was considered a failure from a micro perspective but a success from a macro perspective. Drawing on the results of the first phase,

Table 1 Development of the grain for green policy. Source: Prepared by the authors based on Jin and Yabuta (2017, 2020, 2023)

Period (Distinguish)	Policy objectives	Policy object geography	Policy instruments			Policy-related laws, regulations, etc.	Policy evaluation, etc.
			Major regulatory policies	Major incentive policies			
				Subsidy	Supportive Policies for Farmers		
Before (1949–1998)		Areas with slopes of 25° or more, desertification, and other severe conditions that weaken the ecological environment				1957.Provisional Guidelines for Water and Land Conservation in the People's Republic of China 1985.Ten-point policy on the further development of the rural economy	
Pilot (1999–2001)	Improve ecological environment, adjust rural industrial structure, increase farmers' income	Areas with slopes of 25° or more, severe water and soil loss, desertification, etc., weak ecological environment, and low food productivity (Started in Sichuan, Shaanxi, and Gansu, and fully implemented in 25 provinces, autonomous regions, and municipalities nationwide, excluding Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, and Guangdong)	Management right of the planted forest area: 50 years Reforestation: Ecological forest area is about 80% of the total retired forest area (5 years for economic forest and 8 years for ecological forest) Post-forestry protection: ecological immigration, no mountain herding	South:2 250kgg/ha North:1 500 kg/ha livelihood assistance:300 RMB/ha Silvicultural Subsidies:750 RMB/ha	Support for the transfer of leisure labor to other industries (manual labor, forest economy, fruit and specialty product production, cattle ranching, forest travel, etc.); tax breaks for agriculture	1999.Grain for Green, closing mountains for greening, using food instead of charity, individuals are responsible 2000.Interim measures for the supply of food for Grain for Green (JiLiangBan [2000] No. 241) 2001.Notification of ecological and economic forest certification standards for the Grain for Green process (LinTuiFa[2001] No.550)	1) Improvement of the ecological environment Retention of 2.3 million hectares of forest (2) Adjustment of rural industrial structure (3) Increase agricultural income

Table 1 (continued)

Period (Distinguish)	Policy objectives	Policy object geography	Policy instruments			Policy-related laws, regulations, etc.	Policy evaluation, etc.
			Major regulatory policies	Major incentive policies			
				Subsidy	Supportive Policies for Farmers		
Phase 1 (2002–2012)			Management right of the planted forest area: 70 years Reforestation: At least 80% of the area of retired forest must be ecological forest (5 years for economic forest and 8 years for ecological forest) Post-forestry protection: ecological immigration, no mountain herding Logging after the period: in accordance with the law	South: subsidy (2004–2006) 3 150 RMB/ha South: extension (2007–2012) 1 575RMB/ha Nouth: subsidy (2004–2006) 2 100 RMB/ha Nouth: extension (2007–2012) 1 050 RMB/ha livelihood assistance:300 RMB/ha Silvicultural Subsidies:750 RMB/ha		2002.Several Opinions on Further Improving Measures for Grain for Green policy (GuoFa (2002) No. 10) 2003.The Grain for Green Ordinance 2004.Notice on Improving Food Subsidies in the Grain for Green Policy (GuoBanFa [2004] No.34) 2007.Notice on the Improvement of Grain for Green Policy (GuoFa [2007] No.25) 2007.China's National Response to Climate Change 2010.Central No. 1 Document Announced 2010.Notice on Improving Grain for Green Operations in 2010 (LinTuiFa [2010] No. 32)	(1) Improvement of the ecological environment Retention of forest area of 6,967,000 ha (2) Adjustment of rural industrial structure (3) Increase agricultural income Farmers' disposable income
Preparatory (2013)						2013.On Policy Recommendations for Integrating New Grain for Green and Grain for Green Results 2013.Preparation of a new total program for returning farmland to forest and grass	

Table 1 (continued)

Period (Distinguish)	Policy objectives	Policy object geography	Policy instruments			Policy-related laws, regulations, etc.	Policy evaluation, etc.
			Major regulatory policies	Major incentive policies			
				Subsidy	Supportive Policies for Farmers		
Phase 2 (2014–2020)	Improve ecological environment, adjust rural industrial structure, increase farmers' income, escape poverty	Priority will be given to poor areas (where the poor population is concentrated) among areas with a weak ecological environment and low food productivity due to slopes of more than 25°, water and soil loss, and desertification. (2014: Shanxi, Hubei, Hunan, Guangxi, Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Henan, Tibet, Shaanxi, Gansu, Ningxia, Xinjiang, Qinghai, etc.)	Management right of the planted forest area: 70 years Reforestation: 80% or more of the area of retired forest must be ecological forest (5 years for both economic and ecological forest) Post-forestry protection: ecological immigration, no mountain herding Logging after the period: in accordance with the law	1 year of fallowing = 12 000 RMB/ha 3 years of fallowing = 4 500 RMB/ha 5 years of fallowing = 6 000 RMB/ha	Increase subsidies to farmers who have retired from farming Focus on poor areas. Construction of economic forests (oil tea, walnuts, and other woody oils). Improving the ecological environment of poor areas through the participation of the poor population, and promoting forest tourism Production of valuable tree species and unique fruits and the economy under the forest Strengthen and expand subsidies to rural communities. Tax reduction for agriculture	2014.New Total Program for Grain for Green (FaGaiXiBu [2014] No. 1772) 2015.Notice for Accelerating the Mission of Returning the Newly Grain for Green (FaGaiXiBu[2015] No.2502) 2015.Notice on the expansion of the scale of the new Grain for Green herb (CaiNong [2015] No. 258) 2016.Implementation of China's 2030 Sustainable Development Agenda Country Plan—Forestry Action Plan 2016.Central No. 1 Document Announced 2018.Forestry Ecological Protection and Restoration Funds Management Law (Cai Nong [2018] No. 66)	(1) Improvement of the ecological environment Retired forest area: 5,333,000 ha (2) Adjustment of rural industrial structure (3) Increase agricultural income Farmers' disposable income of 10,204 yuan in 2016 (4) Poverty alleviation Poverty reduction and reforestation in poor areas from 2016

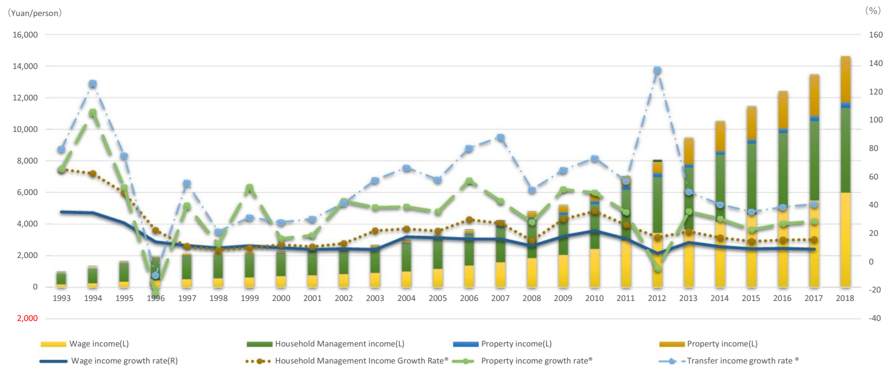


Fig. 2 Composition of and trends in farmers' income. Source: Prepared by the authors based on Jin and Yabuta (2017) and the China Rural Statistics Yearbook (2019)

the second phase was implemented in 2014. Xu et al. (2004), Liu (2005), Qu and Yabuta (2006), and Trac et al. (2007) examined the failure of the first phase of the GFG policy by regionally analyzing the policy's objectives of increasing forest area and farmers' income. According to the State Forestry Administration[1] (2014), the first phase of the GFG policy was positively evaluated from a nationwide perspective because it achieved ecological environment conservation and increased farmers' income in China. The National Forestry and Grassland Administration (2020) reported that the second phase of the GFG policy improved the ecological environment by improving water and land runoff; it also increased farmers' income. In addition, the government found that the poverty-stricken areas targeted by the policy were able to eschew poverty, and that the rural industrial structure was adjusted through a conversion to pastoral industries and fruit production. Previous studies that highlight successful cases include Liu et al. (2008), Liu et al. (2010), and Peng et al (2022). Macroeconomic data show that during the implementation of the GFG policy, forest areas (Fig. 1) and farmers' income (Fig. 2) increased, and that the GFG policy was effective in both the first and second phases. Moreover, over the course of 20 years of the GFG policy, previously degraded forests have undergone recovery and have generated various ecosystem services. Consequently, several studies have the traced positive impact of the GFG policy (Chen et al. 2022; Li et al. 2022; Ma et al. 2022; Xu et al. 2022). For instance, He et al. (2022) analyzed the implementation of the GFG policy in relation to the restoration of regional ecosystems.

Meanwhile, Feng et al. (2005) conducted a simulation analysis to examine the impact of the GFG policy on grain supply. Further, Bai et al. (2021) researched the effects of the GFG policy on agricultural economic growth, whereas Treacy et al. (2018) focused on farmers' migration. Lei et al. (2023) investigated the influence of the GFG policy on farmers' well-being. Additionally, Deng et al. (2014) analyzed

[1] In 2018, the State Forestry Administration was renamed the National Forestry and Grassland Administration (Jin and Yabuta 2023).

the factors driving changes in soil organic carbon resulting from the GFG policy. Finally, Fang et al. (2022) explored the effects of the GFG policy on ecosystem services.

Quantitative analyses of the GFG policy have been conducted by Zhang et al. (2021), who conducted a logistic regression analysis on the impact of GFG policies on forest recovery and Yu's (2016) multinomial logit model analysis on the willingness to pay for environmental benefits, and its impact factor based on a questionnaire survey of farmers in Wanzhou, Chongqing. In addition, You et al. (2022) used a probit model to analyze the impact of GFG policies on farmers' happiness. In addition, Peng et al. (2022) used SEM analysis to analyze the main factors that make farmers accept GFG policies.

In other words, a factor analysis of the variables involved in the conversion of agricultural land to forest land is required. While many previous studies are based on field surveys, few have conducted econometric analyses using economic theory models. Jin and Yabuta's (2020) study is one exception; they conducted a factor analysis using a multiple regression analysis with a brief development of the economic theory model and data from the first phase, namely 2002–2010.

Considering the aforementioned research gap, this study aimed to analyze the GFG policy by constructing a land use model. First, we revised Jin and Yabuta's (2020) theoretical model. Next, we conducted a factorial analysis of the first and second periods and improved the data quality. Third we, performed a comparative analysis using the two-stage least squares (2SLS) analysis with panel data to overcome endogeneity concerns. The novelty of this research lies in conducting a comprehensive analysis of the factors influencing the diffusion of afforestation policies using data from both the first and second phases under the theoretical framework of the GFG policy model.

This study's findings are expected to assist in developing appropriate forest restoration policies in regions characterized by low productivity and fragile ecological environments, especially developing countries. For example, analyzing policy factors for different time periods in countries with varying levels of economic development and researching subsidy policies in regions with differing levels of productivity can be valuable not only for policy initiators but also for policy implementers.

The remainder of this paper proceeds as follows. In Sect. 2, we construct an economic model and conduct a comparative static analysis of China's GFG policy. In Sect. 3, based on the results of the model analysis, we conduct a panel data analysis using the 2SLS method with province-specific data, with the GFG area as the explained variable. In Sect. 4, we provide an overview of this study and summarize the issues related to retraining and returning forest policies.

2 A model analysis of China's GFG policy

From the perspective of land use by farmers, the GFG policy implies a shift from cultivated land to forest land. Farmers will retire and return forests when the marginal returns from cultivation of the land they use are less than the marginal returns they could earn by converting the land to forest land. This model helps clarify farmers' independent choice regarding land use. Assuming a model in which land use is simply divided into two types, agricultural land and forest land, we consider the benefits of each type (Bai et al. 2021; Jin and Yabuta 2020; Yabuta and Yamanishi 2007).

Under the GFG policy, many farm households convert a portion of their arable land to forest land and increase their income by transferring surplus labor to alternative industries. Based on this status quo, we denote the farmer's agricultural area as n, forest area as s, and total area as u. Let L denote the total labor of farm households; L_1, the labor input in agriculture; and L_2, the labor input in forestry.

Furthermore, let p_2 be the price of logs; $p_{1,}$ the price of agricultural products; and a[2] and b, the subsidies per hectare for agriculture and forestry, respectively. A farmer's total income (Π) is the sum of agricultural income (Π_1) and forestry income (Π_2). In this section, we consider a model in which labor is allocated to agriculture and forestry, assuming only agricultural and forestry land use. The production functions of agriculture and forestry with respect to farmers are assumed to be Cobb–Douglas functions.

First, we consider land use. The farmer has only u available land in total, which is used as either farmland (n) or forest land (s). Let $Y = F\left(n, L_1\right)$ be the production function of agricultural products. In rural China in the 2000s, agriculture was not extensively mechanized; consequently, the profitability of agriculture is assumed to be dependent on land and labor. In addition, the fertility of the land is assumed to be uniformly distributed, since the areas where the GFG is implemented are on slopes of 25° or more, and productivity is low. A farmer's income from farming is defined as the sales of the agricultural products produced and sold, minus the cost of producing them, plus any positive government subsidies from farming. Regarding farmers' benefits (income) from farmland,

$$\Pi_1 = p_1 F\left(n, L_1\right) - C_1\left(n + L_1\right) + an, F = n^{\alpha} L_1^{\beta}, F\prime > 0, F'' < 0, C_1\prime \left\langle 0, C_1'' \right\rangle 0, \tag{1}$$

where p_1 is the price of agricultural products, F is the output of agricultural products (production function), C_1 is the total cost, and a is the agricultural subsidy per hectare. In accordance with the regulations on GFG, when land s is GFG area, it is either replanted as an ecological forest or used as an economic forest, such as bamboo forest or fruit tree forest. $F\prime$ and F'' are the first- and second-order conditions for profit maximization for farmers with agricultural land. $C_1\prime$ is the first-order condition for the cost of farming and C_1'' the second-order condition. $C_1\prime$ is assumed to be constant with the scale of production. The ratio is generally set at 4:1; however, for simplicity, we assume the sustainable use of logs. Regarding the income of farmers from forest land:

[2] With regard to agriculture, the Hu Jintao–Wen Jiabao regime, which began in 2003, emphasized agricultural development. This led to a reduction in agricultural taxes in 2003 and the elimination of agricultural taxes in 2006. The subsidies here include subsidies under the GFG policy, that is, subsidies per hectare of land that has been returned to cultivation.

For simplicity, this study includes income from economic forests under agricultural income. For returned forest land, only income from logs is considered. Here, we assume that the farmer will cut down trees a certain period of time after planting. In other words, under a discount rate r, farmers are considered to rotate, with the present value of profit in the first period being $[p_2Q(s) - C_2]e^{-rT1}$ and the present value of profit in the second period being $[p_2Q(s) - C_2]e^{-rT2}$, repeated indefinitely, the sum of which is as follows (Amacher et al. 2009; Zhang and Pearse 2012):

$$Z = \sum_{i=1}^{\infty} \left[p_2Q(s, L_2) - C_2\right]e^{-rTi} = \left[p_2Q(s, L_2) - C_2\right]/\left(e^{rTi} - 1\right).$$

Equation (2) was developed with reference to the above equations. Here, we assume $\Lambda = 1$ in Eq. (2) without loss of generality.

$$\begin{aligned}\Pi_2 = &\frac{\left\{\left[p_2Q(s, L_2) - C_2(s + L_2)\right]/\left(e^{rT} - 1\right)\right\}}{t} \\ &+ bs, Q = s^{\gamma}L_2^{\delta},\ \Lambda \equiv \left(e^{rT} - 1\right), Q\prime > 0, Q'' < 0, C_2\prime\left\langle 0, C_2''\right\rangle 0.\end{aligned} \tag{2}$$

Here, Λ is the current discount rate, p_2 is the price of logs, $Q(s, L_2)$ is the production of logs, C_2 is the total cost of growing logs, r is the discount rate, T is the standard age of timber, and t is the time until harvest. In addition, b is the per-area subsidy for the retreatment and return of forests. $Q\prime$ and Q'' are the first- and second-order conditions for maximizing farmers' profit from forest land. $C_2\prime$ is the first-order condition for the cost of forestry and C_2'' is the second-order condition.

The labor input in agriculture is calculated using the Eq. (1) formula,

$$L_1 = \beta p_1 Y/C_1, \tag{3}$$

and the farmland to be input is,

$$n = \alpha p_1 Y\left[C_1 - a\right]. \tag{4}$$

Similarly, for forest land, from Eq. (2),

$$L_2 = \delta p_2 Q/C_2,\ s = \gamma p_2\left[C_2 - b\right]. \tag{5}$$

From Eq. (3)–(5), the relationship between labor and land use is

$$L_1 = \left\{\beta\left(C_1 - a\right)/\alpha C_1\right\}n,\ L_2 = \left\{\delta\left(C_2 - b\right)/\gamma C_2\right\}s. \tag{6}$$

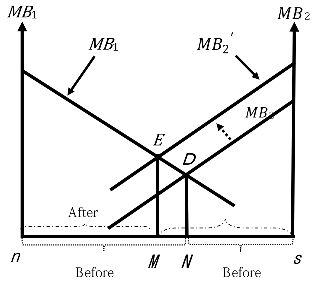
The land and labor constraints are

$$\overline{u} = n + s \text{ and } \overline{L} = L_1 + L_2, \text{respectively.} \tag{7}$$

However, the land use equilibrium condition assumes that the marginal benefits of agricultural and forest land use are equal:

The marginal benefit of agricultural land $(MB_1) = \frac{\partial \Pi_1}{\partial n} = p_1\alpha\left(\frac{\beta(C_1 - a)}{\alpha C_1}\right)^{\beta} n^{(\alpha+\beta)-1} - (C_1 - a)$, and the marginal benefit of forest land $(MB_2) = \frac{\partial \Pi_2}{\partial s} = p_2\gamma\left(\frac{\delta(C_2 - b)}{\gamma C_2}\right)^{\delta} s^{(\gamma+\delta)-1} - \left(C_2 - b\right)$,

Fig. 3 The grain for green model. Source: Prepared by the authors



such that $MB_1 = MB_2$. Based on the above, the system is closed with L_1, L_2, n, and s as unknowns in Eqs. (6), (7), MB_1, and MB_2, respectively, with respect to the farmer's land use and labor.

This situation can be illustrated using the land allocation model shown in Fig. 3. The land allocation of the farmer before the implementation of the GFG policy is at point D, where MB_1 and $MB_2\prime$ intersect with nN agricultural land and Ns forest land for land use. In such a situation, farmers receive incentives from the government (e.g., subsidies) to participate in the GFG policy. In this case, farmers shift the MB_2 to the upper left side of the MB_2 curve by returning forests to areas where farmland productivity is low. This shift results in $MB_1 = MB_2$ at the new equilibrium point E, and land use is determined at point M. Thus, the implementation of the GFG policy results in an increase in the NM portion of forest land (GFG) for farmers, as the MN portion of farmland is removed from cultivation.

Note: MB_1: marginal benefit from agricultural land; MB_2: marginal benefit from forest land.

The right side from point n is agricultural land and the left side from point s is forest land.

The equilibrium is given by $MB_1 = MB_2$, which is denoted by point E in Fig. 3. As the model shows, the equilibrium equation $MB_1 = MB_2$ is considered for calculating farmers' land use, provided that MB_1 is equal to MB_2. For this equilibrium point E, we focus on changes in forest use relative to prices, subsidies, and wages, among others:

$$\Gamma\left(s;p_1,p_2,a,b,Z\right) = 0. \tag{8}$$

In Eq. (8), the variable Z refers to the technical parameters of the production function that affect s, marginal cost, etc. Assuming $\Gamma_{p_1} > 0, \Gamma_{p_2} < 0, \Gamma_a > 0, \Gamma_b < 0$, and $\Gamma_s > 0$, for practical implications, the comparative static result is

$$\frac{\mathrm{d}s}{\mathrm{d}p_1} = -\frac{\Gamma_{p_1}}{\Gamma_2}\left\langle 0, \frac{\mathrm{d}s}{\mathrm{d}p_2} = -\frac{\Gamma_{p_2}}{\Gamma_2}\right\rangle 0,\ \frac{\mathrm{d}s}{\mathrm{d}a} = -\frac{\Gamma_a}{\Gamma_2}\left\langle 0, \frac{\mathrm{d}s}{\mathrm{d}b} = -\frac{\Gamma_b}{\Gamma_2}\right\rangle 0. \tag{9}$$

With respect to the sign condition here, we assume that a decrease in MB_1 or an increase in MB_2 will increase s. The first term in Eq. (9) implies that an increase in the price of agricultural commodities will decrease the GFG area, whereas the second term implies that an increase in the price of logs will increase the GFG area. In addition, the third term implies that an increase in agricultural subsidies will lead to a decrease in the GFG area, whereas the fourth term implies that an increase in subsidies related to GFG will lead to an increase in the GFG area.

The construction and analysis of a theoretical model of the GFG policy from an economics perspective clarified the factors that affect the GFG area when the GFG policy is implemented. In the following section, an empirical analysis is conducted based on the results of the theoretical model (Eqs. (8) and (9)). Equation (8), the implicit function obtained from the equilibrium point E in Fig. 3, is used as the regression equation. Based on the results of the static analysis in Eq. (9), an empirical analysis is conducted to determine whether the factors that affect the GFG area have a positive or negative effect as per the sign.

3 Empirical analysis of the policy of retrenchment and return of forests

3.1 Model estimation and data

Numerous studies have examined individual cases to evaluate the GFG policy. In this section, we conduct a quantitative analysis of the GFG policy based on the model analysis described in Sect. 2. In the equilibrium model for land use, the factors that determine the level of MB_2 or MB_1 are important. With respect to GFG, we perform a panel data analysis on provincial data for China using regression analysis with the GFG area as the explained variable, which is the objective of this analysis. As indicated in the model analysis in Sect. 2, all the variables on the left-hand side of Eq. (8) can be considered as factors that determine the land allocation related to the implementation of the GFG policy. Therefore, in this study, we regress the following equation:

$$\begin{aligned} LOG\left(GGA_{it}\right) &= \alpha + \beta_1 WP_{it} + \beta_2 FP_{it} + \beta_3 LOG\left(GGI_{\boldsymbol{it}}\right) + \beta_4 LOG\left(AS_{it}\right) + \beta_5 dummy_{it} \\ &+ \beta_6 nsdummy_{it} + \beta_7 LOG\left(rural_{it}\right) + \beta_8 X_{it} + \beta_9 NS_{it} + \beta_{10} LOG\left(SA_{it}\right) + FE_t + FE_i + u_{it}. \end{aligned} \tag{10}$$

The variables in the theoretical model are used whenever possible. In Eq. (10), GGA_{it} is the GFG area, Wp_{it} is the wood price, FP_{it} is the food price, GGI_{it} is the investment in GFG, and AS_{it} is the agricultural subsidy. For $dummy_{it}$, the first period (2002–2012) is set to 0 and the second period (2014–2018) is set to 1. The $nsdummy_{it}$ is set to 1 for the south and south below the Yangtze River basin and 0 otherwise (Jin and Yabuta 2023). In addition, $rural_{it}$ represents the rural population density and weather data (temperature, humidity, and rainfall) for the region. X_{it} is $dummy_{it}$ multiplied by the wood price, food price, grain production, investment in GFG, manufacturing wage, service industry wage, and rural minimum livelihood security cost. In other words, it examines whether the impact of the above variables on the GFG area in the first and second periods changed. NS_{it} is $nsdummy_{it}$ multiplied by the wood price, food price, grain production, and investment in GFG, and

Table 2 Basic statistics of the data

Data	Variable name	Data Description	Source	Obs	Mean	Std. Dev	Min	Max
The Greening for Grain area (ha)	lnGGA	Area of GFG in Each Province Each Year + 1	China Forestry Statistical Yearbook	527	20,656.71	51,667.06	1.00	551,601.00
Sown Area (thousand ha)	lnSA	Crop acreage in each province	China Statistical Yearbook	527	5167.33	3650.14	103.80	14,783.40
Wood Price (Yuan/m^3)	WP	Wood price in each province	China Statistical Yearbook	403	517.07	148.20	176.77	1073.95
Food Price (%)	APP	Food price in each province	China Statistical Yearbook	527	175.63	50.11	93.30	273.19
Cereals(10 thousand tons)	lncereal	Production of fir, wheat, corn, etc. in each province	China Rural Statistics Yearbook	527	66,216.34	80,356.97	1.00	852,084.50
Agricultural subsidy (yuan/person)	lnAS	Agricultural subsidy income per capita in each province	China Rural Statistical Yearbook	527	711.87	742.58	0.00	5560.58
Farmer's wage (yuan/person)	lnFW	Farmer's wage income per capita in each province	China Rural Statistical Yearbook	527	2354.26	986.99	0.00	5552.09
The Greening for Grain Investment (10 thousand yuan)	lnGGI	Amount of investment in GFG in each province + 1	China Forestry Statistical Yearbook	527	66,216.34	80,356.97	1.00	852,084.50
Rural Minimum Living Subsidy fee (10 thousand yuan)	lnlivingsubsidy	Rural Minimum Livelihood Security Expenditures in Each Province	China Rural Poverty Monitoring Report	527	2305.65	1716.78	203.63	8000.70
Rural Population (person/ha)	lnnpop	Rural Population Density in Each Province	China Statistical Yearbook	527	14.40	5.06	4.30	25.40
Temperature (℃)	lntemperature	Annual average temperature of major cities in each province	China Statistical Yearbook	527	64.61	11.41	31.00	84.58
Humidity (hPa)	lnhumidity	Average annual humidity in major cities in each province	China Statistical Yearbook	527	20.02	28.05	1.00	115.36
Precipitation (mm)	lnprecipitation	Precipitation in major cities in each province for the entire year	China Statistical Yearbook	527	902.74	523.56	74.90	2939.70
Livestock (10 thousand head)	lnlivestock	Number of livestock owned by each province	China Rural Statistical Yearbook	527	414.6573	328.326	1.2	1558.6

Table 2 (continued)

Data	Variable name	Data Description	Source	Obs	Mean	Std. Dev	Min	Max
Fruit (tons)	lnfruits	Fruit production in each province	China Rural Statistical Yearbook	527	2,833,855	4,871,770	0.2	27,900,000
Unenrolled student (person)	lnUS	Unenrolled students in each province	China statistical yearbook	527	7535.829	18,106.63	237	150,815

Data are from China Bureau of Statistics (2002-2019), National Forestry and Grassland Administratio (2002-2019), and Rural Survey Organization National Bureau of Statistics (2002-2019)

GFG grain for green

the above variables are used to examine the difference between the north and south during the first period. FE_i is a region dummy, FE_t is a year dummy, and u_{it} is an error term. i represents the province, city, or autonomous region of China, and t represents time. See Table 2 for the specific data.

The data used in the analysis were from the China rural statistical yearbook, the China forestry statistical yearbook, the China statistical yearbook, and the Poverty Monitoring Report of Rural China.

The data period is 17 years, from 2002 to 2018, and includes 25 provinces in the first period: Beijing, Tianjin, Hebei, Shanxi, Inner Mongolia, Liaoning, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan, Guangxi, Hainan, Chongqing, Sichuan, Guizhou, Yunnan, Tibet, Shaanxi, Gansu, Qinghai, Ningxia, and Xinjiang. The target area for the second phase is almost the same as that for the first phase; however, the focus is on the western region, where there is a higher concentration of poor areas.

The land allocation model is a simultaneous equation consisting of marginal benefit curves for agricultural land and forest land. Although the crop and GFG areas are determined simultaneously at the point where the marginal benefit curves of farmland and forest land coincide, the simultaneous determination model suffers from an endogeneity problem. For example, if a correlation is observed, in that a decrease in farmland leads to an increase in forest land, another correlation may exist, in that an increase in forest land leads to a decrease in farmland, which is estimated using the two-step least squares method. In doing so, we consider food prices and wage income as operating variables that affect farmland but not forest land. The following equation is used for the first stage of estimation:

$$LOG\left(SA_{it}\right) = \lambda_1 + \lambda_2 FP_{it} + \lambda_3 LOG\left(WI_{it}\right) + \eta_{it}, \tag{11}$$

where SA_{it} is the crop area, FP_{it} is the food price, and WI_{it} is the farmer's wage income.

During the 2SLS analysis, we control for region and year dummies, as well as for population density and weather data, which represent regional characteristics, while also checking for robustness. We also estimate fixed and variable effect models for a 2SLS estimation and then conduct Hausman tests (Baltagi 2008; Kitamura 2004).

3.2 Analytical results and policy implications

Using the results of the above estimates, we examine the factors that affect the GFG area over the entire period and the differences between the southern and northern areas in the first period, in addition to the differences in the variables between the first and second periods. The results of the analysis in Table 3 are estimated by fixed effect (FE) (Eqs. (1)–(4)) and random effect (RE) (Eqs. (5)–(8)) using the 2SLS method, followed by the Hausman test, resulting in the adoption of the FE modes (1) through (4). First, the estimated result for crop area is negative and not statistically significant. Although not statistically significant, the sign is negative, indicating that as the crop area decreases (increases), the GFG area increases (decreases), as in the theoretical model. Wood prices are positive but not statistically significant, as the

Table 3 Analysis results

	(1) FE	(2) FE	(3) FE	(4) FE	(5) RE	(6) RE	(7) RE	(8) RE
Crop Area (Log)	– 0.204 (13.263)	– 0.341 (12.997)	– 1.744 (13.778)	– 2.179 (13.885)	– 1.547 (1.591)	– 1.032 (1.021)	– 1.027 (0.819)	– 1.307 (1.136)
Wood Price	0.008 (0.015)	0.009 (0.015)	0.007 (0.017)	0.008 (0.017)	0.018*** (0.006)	0.020*** (0.005)	0.013* (0.008)	0.015*** (0.005)
Food Prices	– 0.179*** (0.059)	– 0.181*** (0.055)	– 0.166*** (0.056)	– 0.167*** (0.054)	– 0.098*** (0.031)	– 0.101*** (0.030)	– 0.044 (0.051)	– 0.058 (0.059)
GFG Investment (Log)	1.618*** (0.371)	1.641*** (0.400)	1.564*** (0.367)	1.593*** (0.406)	0.269*** (0.085)	0.261*** (0.088)	0.211** (0.085)	0.215** (0.086)
Agricultural Subsidy (Log)	– 2.688 (1.654)	– 2.5 (1.665)	– 3.543 (2.367)	– 3.327 (2.385)	– 2.337** (0.921)	– 2.227** (0.889)	– 3.066*** (1.063)	– 3.456*** (1.178)
Dummy × Wood Price	– 0.014 (0.023)	– 0.014 (0.023)	– 0.015 (0.027)	– 0.014 (0.027)	– 0.012* (0.006)	– 0.013** (0.006)	– 0.002 (0.010)	– 0.005 (0.009)
Dummy × food prices	0.096** (0.041)	0.097*** (0.037)	0.122* (0.066)	0.121* (0.065)	0.109*** (0.035)	0.111*** (0.034)	0.068 (0.049)	0.076 (0.052)
Dummy × GFG Investment (Log)	0.520*** (0.096)	0.516*** (0.102)	0.503*** (0.136)	0.502*** (0.145)	0.343*** (0.093)	0.337*** (0.088)	0.356*** (0.112)	0.378*** (0.110)
Dummy × Agricultural Subsidy (Log)	3.150** (1.455)	2.819** (1.325)	4.414** (1.977)	4.106** (1.898)	3.089* (1.726)	3.001* (1.661)	4.792** (2.360)	4.849* (2.659)
Dummy	– 23.790** (9.755)	– 21.792** (10.195)	– 34.613*** (13.268)	– 32.655** (13.582)	– 33.496*** (11.989)	– 33.258*** (11.661)	– 43.559*** (15.809)	– 42.290** (17.527)
First Period dummy × Nsdummy × Wood Price	– 0.027 (0.021)	– 0.027 (0.020)	– 0.032 (0.027)	– 0.03 (0.027)	– 0.030*** (0.007)	– 0.032*** (0.006)	– 0.021** (0.009)	– 0.025*** (0.008)
First Period dummy × Nsdummy × Food prices	0.051 (0.032)	0.054* (0.030)	0.062* (0.036)	0.065* (0.034)	0.066*** (0.025)	0.067*** (0.026)	0.044* (0.023)	0.046* (0.026)
First Period dummy × Nsdummy × Agricultural Subsidy (Log)	– 0.59 (0.914)	– 0.754 (0.889)	– 0.827 (0.919)	– 0.977 (0.890)	– 0.931 (0.775)	– 0.925 (0.774)	– 0.531 (0.741)	– 0.464 (0.781)

Table 3 (continued)

	(1) FE	(2) FE	(3) FE	(4) FE	(5) RE	(6) RE	(7) RE	(8) RE
Westdummy					1.292** (0.527)	1.313** (0.524)	1.375** (0.582)	1.320* (0.692)
Nsdummy					– 0.673 (1.295)	– 1.456 (1.148)	– 1.134 (1.268)	– 1.416 (1.296)
_cons	41.522 (83.183)	90.564 (71.034)	– 5.85 (111.985)	45.748 (104.298)	32.250** (13.189)	23.514*** (7.240)	37.678*** (12.622)	37.896*** (12.155)
Population Density	YES	YES	NO	NO	YES	YES	NO	NO
Weather	YES	NO	YES	NO	YES	NO	YES	NO
Regional Dummy	YES	YES	YES	YES	YES	YES	YES	YES
Year Dummy	YES	YES	YES	YES	YES	YES	YES	YES
N	370	370	370	370	370	370	370	370

GFG grain for green, *FE* fixed effect, *RE* random effect

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively

Standard errors are in parentheses

sign is the same as in the results of the analysis in the theoretical model. An increase in timber prices implies an increase in the GFG area. This can be interpreted as the increase in timber prices having an effect based on the expectation of income from timber for farmers participating in the GFG policy.

Conversely, food prices have the same negative impact as in the theoretical model results and are statistically significant at 1%. This means that a one-unit increase in food prices decreases the GFG area by – 16.6 to – 18.1%. An increase in food prices implies a decrease in GFG area. This can be interpreted as farmers determining that, when food prices rise, income from cultivation is greater than income from GFG for a certain land area.

Furthermore, the sign is positive and statistically significant at the 1% level for the amount of investment in GFG. This means that a 1% increase in government investment in GFG increases the GFG area by 1.5–1.6%. In other words, an increase in investment in GFG can be interpreted as an increase in the GFG area. This can be understood as an incentive for farmers to choose GFG over cultivation when increasing the investment in GFG. This aligns with the findings of Peng et al. (2022).

In addition, when examining the impact of agricultural subsidies, the sign is negative and statistically insignificant. The sign is consistent with the theoretical model. This can be interpreted as farmers perceiving that, when agricultural subsidies increase for a certain land area, income from cultivation is greater than income from GFG. This aligns with the findings of Trac et al. (2007).

Next, we examine the differences in the variables that affected the GFG area in the first and second periods. We find that wood prices are not statistically significant. This variable does not have a greater impact in the second than in the first period. By contrast, food prices, the amount of investment in GFG, and agricultural subsidies are statistically significant at the 5% level. This implies that food prices, the amount of investment in GFG, and agricultural subsidies had a greater impact on the GFG area in the second period than in the first period.

Finally, we examine the differences in wood prices, food prices, and agricultural subsidies to the GFG area in the south and north during the first period. Wood prices and agricultural subsidies are negative and statistically insignificant whereas food prices are positive and statistically significant. This implies that food prices in the south are more influential than in the north in the first period.

The analysis of the data for both periods shows the effect of each variable on the GFG area and whether each variable was more or less effective in the first period than in the second period. However, it is also necessary to analyze the effect of each variable on the GFG area in each period. Therefore, we examine the effects of crop area, forest product prices, food prices, investment in GFG, and agricultural subsidies in the first (Eqs. (1)–(4)) and in the second period (Eqs. (5)–(8)) with reference to Table 4. The analyses for the first and second periods are also subjected to Hausman tests and resulted in the adoption of the FE model.

First, the sign of the crop area is negative in both the first and second periods, with the second period being statistically significant. This means that in the first and second periods, as the area of agricultural crops decreased, the GFG area increased. Thus, the GFG policy evidently increased the planting of trees on cultivated land and its conversion to forest land. Based on these results, the introduction of a GFG

Table 4 Analysis results

	(1) FE	(2) FE	(3) FE	(4) FE	(5) FE	(6) FE	(7) FE	(8) FE
Crop area (Log)	– 0.376 (12.005)	– 6.828 (12.050)	– 7.861 (8.692)	– 11.1 (8.878)	– 8.356* (4.600)	– 9.506* (5.032)	– 10.880* (6.362)	– 13.155* (7.920)
Wood Price	– 1.372 (1.213)	– 1.284 (1.200)	– 1.16 (1.291)	– 1.118 (1.256)	– 1.416** (0.570)	– 1.632** (0.662)	– 1.432** (0.598)	– 1.727** (0.752)
Food prices	– 0.096** (0.039)	– 0.096** (0.042)	– 0.063** (0.031)	– 0.072*** (0.027)	0.106*** (0.033)	0.115*** (0.041)	0.132** (0.059)	0.152* (0.084)
GFG Investment (Log)	0.93 (0.581)	0.883 (0.785)	0.664 (0.588)	0.713 (0.846)	0.947*** (0.323)	1.003*** (0.357)	1.097** (0.460)	1.210** (0.592)
Agricultural Subsidy (Log)	– 1.282 (1.034)	– 1.169 (1.066)	– 1.153 (1.170)	– 1.166 (1.163)	0.396 (0.485)	0.491 (0.504)	0.93 (1.084)	1.19 (1.371)
Nsdummy × GFG Investment (Log)	– 1.465** (0.684)	– 1.390* (0.769)	– 1.225* (0.651)	– 1.278 (0.781)				
Rural subsistence allowance (Log)					2.292*** (0.091)	2.281*** (0.095)	2.311*** (0.100)	2.302*** (0.110)
Dummy2016					– 4.933* (2.543)	– 5.508* (2.853)	– 5.836 (3.896)	– 6.892 (5.121)
_cons	88.663 (82.917)	161.693** (72.404)	86.276 (86.645)	159.466** (77.870)	101.296 (61.739)	111.418* (67.114)	64.552 (40.613)	70.477 (45.171)
Population Density	YES	YES	NO	NO	YES	YES	NO	NO
Weather	YES	NO	YES	NO	YES	NO	YES	NO
Regional Dummy	YES	YES	YES	YES	YES	YES	YES	YES
Year Dummy	YES	YES	YES	YES	YES	YES	YES	YES
N	237	237	237	237	224	224	224	224

GFG grain for green, *FE* fixed effect, *RE* random effect

***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively

Standard errors are in parentheses. In the first phase of the analysis, unenrolled students (The poorer the area, the lower the rate of higher education.), fruit production, and number of livestock were added as control variables policy should be considered, especially in low-productivity areas where forests are cut down to make way for cultivated land. Further, the investment in GFG had a positive impact on the GFG area in both the first and second periods. In particular, in the second period, a 1% increase in investment in GFG implies a 0.9%–1.2% increase in the GFG area. Conversely, agricultural subsidies are negative in the first period, similar to the results of the theoretical model, but positive in the second period, contrary to the results of the theoretical model. Neither the first period nor the second period is statistically significant. Therefore, the amount of investment in GFG has a positive impact on the expansion of the GFG area, and the government should actively increase the amount of investment when implementing the GFG policy. In addition, the number of agricultural subsidies in the first and second periods could be interpreted as not having had an impact on the choice of farmland over GFG.

Contrary to the hypotheses of the theoretical model, wood prices negatively impacted the GFG area, in both the first and second periods. This suggests that timber prices did not provide an incentive for farmers to participate in the GFG policy in either the first or second phase. This highlights the need for further marketization of the timber market.

Furthermore, during the first phase, different amounts of investment per area were implemented in the south and north, and the impact of these different amounts of investment on the GFG area was negative and statistically significant at 1%. This means that the impact was greater in the north, where fewer subsidies were implemented, than in the south. In the north, where subsidies per area were lower than in the south, the amount of investment in GFG was more attractive to farmers; however, in the south, the amount of investment in GFG was less attractive compared to their agricultural income. Thus, while a unified subsidy could be considered in determining the amount of investment in GFG, different subsidies could be effective for a more appropriate policy progression, depending on the productivity of the region.

In the second period, the livelihood security in rural areas was statistically significant at the 1% level; An increase in the livelihood security in rural areas also implies an increase in the GFG area. Thus, when the GFG policy is implemented in rural areas (concentration of poor), in addition to the amount of investment in GFG, the livelihood security in rural areas will contribute to the increase in the GFG area. Therefore, the government should actively increase livelihood security while considering the area's social and financial context to help people eschew poverty.

Lastly, food prices were negative and statistically significant in the first period and positive and statistically significant in the second period. These results may be attributed to various reasons, including the lack of government spending on farmers in the first period, which may have caused farmers to choose cultivated land over forest land to secure their income. In the second period, the signs of food prices were positive. This means that from the second period, in addition to traditional investment in GFG, government spending will also include rural social security benefits, as well as a decline in the working population in rural areas owing to population migration from rural areas to cities (Jin and Yabuta 2023). A variety of factors have contributed toward farmers choosing more forest land and less farmland. In other words, owing to farmers' limited labor force and the rising prices of agricultural products, choosing forest land, which requires relatively less labor input while maintaining a certain level of profit, over farmland led to greater farmer satisfaction.

4 Conclusion

This study focused on the GFG policy, one of China's forest policies. We created and analyzed an economic model: the land use model of the policy. In addition, we conducted a 2SLS econometric analysis of the factors influencing the GFG policy based on a comparative statistical analysis of the model.

The analysis revealed that the amount of investment in GFG and the livelihood security in rural areas had positive impacts on the expansion of the GFG area. Furthermore, food prices and the amount of investment in GFG were found to be more effective in the second period than in the first period. In addition, the effect of the different per-area subsidies implemented in the southern and northern regions during the first period was more pronounced in the northern region, where subsidies were smaller.

Based on the above analysis, not only the Chinese government, but also the governments of developing countries seeking to restore forests, should understand the local economic situation and the timing of the implementation, and implement policies accordingly. To successfully implement the GFG policy, in addition to providing job support to farmers, agricultural productivity and technical assistance, subsidies to farmers, the amount of investment in GFG, and government spending in rural areas (e.g., social security) should be increased. In addition, support for marketing channels for agricultural products, fruits, and meat, among others, and the active use and development of regional characteristics (culture, nature, etc.), as well as support for business start-ups, should also be emphasized. We believe the results of this study can provide valuable insights to developing countries experiencing deforestation due to cultivation and encourage them to consider implementing a GFG-like policy in the future.

Finally, several issues remain unaddressed. For example, the data employed in this study were limited to macro-level province data. In the future, it will be necessary to conduct a region-by-region analysis of the GFG policy based on data from field surveys that consider regional characteristics.

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Declarations

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