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Land Tenure Security and Sustainable Land Investment: Evidence from National Plot-Level Data in Rural China

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Abstract: The linkage between land tenure security and land quality improvement investment is crucial given that the land tenure security system is a widely applied policy tool for the protection of cultivation land in developing countries. Drawing on the triple land tenure security framework, this paper examines the impact of the de jure and the de facto land tenure security on farming households' decisions about using organic fertilizer on their plots in China, based on a national survey dataset covering 2308 plots matched with 962 farming households across 8 provinces in China (Shangdong, Shangxi, Jilin, Zhejiang, Henan, Gansu, Hunan, and Sichuan) from January to July 2013. The empirical results show that the de facto land tenure security affected the use of organic fertilizer by the farming households positively. In comparison, the impact of the de jure land tenure security on the use of organic fertilizer by farming households was modest. It is suggested that the government should implement the policies effectively to promote de jure land tenure security and encourage farming households to make sustainable land investment.

Keywords: natural resource use; land tenure security; sustainable land investment; plot-level data; rural China

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1. Introduction

Global food demand will continue to increase in the following 40 years [1–3]. Ensuring food security is essential for economic development and social stability around the world. However, food production capacity is being threatened by the continuously degrading quality of arable land [4,5], which was maintained at approximately 15 million hectares annually around the world [6]. There is no exception to rural China. According to the survey conducted by the Chinese Ministry of Land and Resources and the Ministry of Agriculture and Rural Affairs, the area of arable land was around 135 million hectares at the end of 2016, of which over 70.5% was low- and medium-grade. Likewise, the data from the Outline of National Land Use Master Plan during 2015–2020 showed that the average decrease in arable land area amounted to 2.13 million hm^2 from 2015 to 2020. The content of organic matter in soil only accounted for 2.08%, which was significantly lower than the average level of 2.5–4.0% in developed countries. Despite the fact that the grain production was reported to have achieved 12 consecutive annual increases from 2004 to 2015 by China's Ministry of Agriculture and Rural Affairs, the grain production was still under tremendous pressure due to poor arable land quality in China. Thus, it is of critical significance to maintain the production capacity of arable land for food security worldwide [7].

The lack of relevant investment in land quality improvement is one of the key driving forces for land deterioration [8,9]. Incentivizing farmers to reduce the use of chemical fertilizer and increase the use of green maturing (such as organic fertilizer) are the two major measures to maintain land quality [10]. Land tenure security is closely relevant to small farmers' chemical and/or organic fertilizer use. On the one hand, farmers are more likely to reap the rewards of investments within a higher level of land tenure security [11,12]. On the other hand, land abandonment is less likely under a higher level of land tenure security [13,14].

Hence, government policies, which aim to enhance the level of land tenure security by granting formalized property rights through land titling and land formalization, were widely implemented in many developing countries [15,16]. In China, land tenure reform has been carried out since the establishment of the Household Responsibility System (HRS) in 1978. For instance, several rounds of land lease reforms, which aimed at extending the duration of contracts, have been carried out since the 1980s [17,18]. In order to consolidate the achievements of tenure reforms, the central government of China also issued several supplementary policies including the full designation of permanent basic farmland policy in 2015, the pilot work of farmland rotation and fallow policy in 2016, and the Separating Three Property Rights reform in 2016, as well as the Action Plan for 2020 Zero Growth in Fertilizer Usage and so forth [19]. By implementing these policies, the central government of China aims to provide a sufficient top institution design for the implementation of land tenure security reform [20].

However, although national governments have made tremendous efforts to undertake land tenure security reform around the world, its institutional efficiency is still doubted because the area of cultivated land is decreasing and the quality of arable land is degenerating[21]. Land tenure insecurity was observed to be common around the world. On the one hand, some legal land-relevant laws are ambiguous, leading to de jure land tenure insecurity [20]. For instance, China's Constitution stipulates that arable land belongs to the collective. It is complex to identify who the collective is [22]. On the other hand, land-relevant laws are usually implemented ineffectively due to a deficient formal land tenure system, leading to de facto land tenure insecurity [23]. For instance, formal land tenure institutions stipulate that no land be reallocated among households, but in practice, land readjustment still occurs frequently [24,25]. The data from a national-level household survey across China shows that around 60 percent of 2200 households are doubtful about the role of government policies in protecting their land rights [26].

Therefore, it is of crucial significance to investigate the determinants of smallholder farmers' land investment decisions and the role of land tenure within the current tenure regime in the context of rural China. The extant studies have identified demographics, resource endowments, geographical factors, farmers' risk perceptions, off-farm immigration, land tenure insecurity, and so forth [9,11,27]. Although the previous empirical analyses have paid much attention to the role of land tenure (in)security in farmers' land investment decision-making, the findings are mixed. For instance, many studies have identified that insecure land tenure has adverse impacts on farmers' investments in land quality improvement investments [28–31]. By contrast, other studies suggest that land tenure security has negative impacts on smallholder farmers' long-term investment behaviors [15,32,33]. For instance, Nkamleu and Manyong (2005) argued that land tenure insecurity had a positive impact on farmers' certain investments such as adopting live fencing [34]. Similar findings are also obtained by Rao et al. (2016), who concluded that wasteland tenure insecurity could facilitate to adopt crop-tree intercropping in rural

Xinjiang [32]. However, Campos et al. (2023) found that land tenure security could not motivate the households in Nicaragua to make investments in land [31]. Likewise, Adesina et al. (2000) argued that land tenure security was not significantly correlated with farmers' farming practices [35].

Although previous studies have identified the role of land tenure security in farming households' land investments, no consensus has been reached so far. The existing studies have mainly investigated the impact of perceived land tenure security on land investment at the household level instead of at the plot-level [9,28]. To date, there is limited research on the precise linkages between de facto land tenure security and farming households' decisions to use organic fertilizer at the plot-level in rural China.

The general objective of this study is to investigate the linkages between land tenure security and farming households' decision-making behavior of land use in developing countries. Specifically, we aim to examine whether and how de jure and de facto land tenure security affects farming households' use of organic fertilizer in rural China. It makes both theoretical and empirical contributions to the debate on the impacts of land tenure security on long-term land investment by farming households. In particular, it contributes to the current research by fulfilling the following research gaps. First, we have conducted an empirical analysis by using a representative nationwide dataset at the plot-level. The advantage of this is that under HRS, original arable land allocation and subsequent land adjustment, are basically based on the number of agricultural laborers and land quality under an equalitarianism principle [7,36]. Thus, the landholdings of each farming household consist of the plots with different land quality. This implies that land fragmentation is typical and plot characteristics play a crucial role in influencing farming households' decision-making of land use [37]. The findings derived from the plot-level analysis in rural China can provide more specific policy recommendations for handling land fragmentation and induce sustainable land use. Second, we have measured land tenure security from both de jure and de facto perspectives. There are three different types of land tenure security including de jure (legal), de facto (factual), and perception [19,23,38]. In rural China, de jure land tenure security of farming households' was enhanced tremendously because of the endowed usufruct rights through various land tenure reforms since 1978 [20]. In contrast, de facto land tenure has not been secure [25,39]. The existing literature focuses more on the perception perspective [28,38,40]. It is very important to examine the impact of land tenure security on farming households' decision-making from a more comprehensive and objective perspective. The findings of this article have provided new insights for understanding and assessing the outcomes of long-term land tenure reform in rural China, which offers high implications for other developing countries around the world.

The remaining parts of this article proceed as follows: Section 2 lays out a general explanation of the interlinks between land tenure and farming households' investment decision-making, which is followed by the research methodology in Section 3. Section 4 shows empirical evidence, including the model specification, variable definition, estimation strategy, estimation results, and the robustness check. Section 5 presents the conclusions, discussions, and policy implications.

2. Theoretical Framework

Farming households' decisions for land investment are usually investigated by using the classical economic theory of utility maximization. Farming households make land investment decisions if the expected utility, derived from its use, is higher than it is currently. We have followed this utility framework and applied a two-stage decision-making model to examine the impact of land tenure security on farming households' land investment decision-making.

A farming household's standard utility function is specified as $U(C_1, C_2) = \ln(C_1) + \theta \ln(C_2)$, where C_1 and C_2 represent the farming households' consumption at stage I and stage II, respectively, and θ is the discount rate. We assume that a farming household's labor force is fixed at each stage. The labor force at stage I and stage II is $\bar{L}_1$ and $\bar{L}_2$, respectively. At each stage, the labor force can be allocated to on-farm work (l^a), off-farm work (l^o), and/or rural land investment (l^i). K_1 is the land-related initial capital. At stage I, farming households can invest initial capital K_1 and on-farm labor force l^a in agricultural production. Then, the agricultural production function for farming households at stage I is $Y_1 = f(K_1 + l_1^a)$. Meanwhile, farming households can also allocate certain labor force l^i to the rural land investment at stage I, thereby increasing the capital stock for stage II, i.e., $K_2 = K_1 + e(l_1^i)$. For the sake of brevity, this paper presumes that for l_1^i, $e(l_1^i)$ is non-decreasing. In addition, farming households' rural land might be readjusted or reallocated by the village after stage I. Moreover, we assume that the probability of tenure reallocation is $\delta \in [0,1]$ and that the function of tenure security at stage II (S_2) is $\delta(S_2(S_1, l_1^i))$. S_2 is the function of tenure security and labor force on rural land investment (l^i) at stage I. We assume that $\partial\delta / \partial S_2 > 0$, $\partial^2\delta / \partial^2 S_2 < 0$, $\partial S_2 / \partial S_1 > 0$, $\partial S_2 / \partial l_1^i > 0$, $\partial^2 S_2 / \partial^2 S_1 < 0$, $\partial^2 S_2 / \partial^2 S_1 \partial l_1^i < 0$, $\partial^2 S_2 / \partial^2 \partial^2 l_1^i < 0$. Therefore, the agricultural production function for a farming household at stage II is $Y_2 = \delta(S_2(S_1, l_1^i)) f(K_1 + e(l_1^i), l_2^a)$. At this point, the problem of maximizing the farming households' utility can be expressed as (1).

$$\begin{aligned} &Max \;\; U(C_1, C_2) = \ln(C_1) + \theta \ln(C_2) \\ &s.t. \;\; \left[f(K_1 + l_1^a) + l_1^o w_1 - C_1\right] + \left[\delta(S_2(S_1, l_1^i)) f(K_1 + e(l_1^i), l_2^a) + l_2^o w_2 - C_2\right] \\ &l_1^a + l_1^o + l_1^i \le \bar{L}_1, l_2^a + l_2^o + l_2^i \le \bar{L}_2, \end{aligned} \tag{1}$$

Given that production and consumption can be separated from each other, the function could be further simplified as follows:

$$\begin{aligned} &Max \;\; (1+r)\left[f(K_1 + l_1^a) + l_1^o w_1\right] + \left[\delta(S_2(S_1, l_1^i))\left(f(K_1 + e(l_1^i), l_2^a) + l_2^o w_2\right) - C_2\right] \\ &s.t. \;\; l_1^a + l_1^o + l_1^i \le \bar{L}_1, l_2^a + l_2^o + l_2^i \le \bar{L}_2 \end{aligned} \tag{2}$$

To address the optimization problem, we replace $l_1^a = \bar{L}_1 - l_1^o - l_1^i$, $l_2^a = \bar{L}_2 - l_2^o - l_2^i$ in function (2) and solve the first-order condition.

$$\begin{aligned} &-(1+r) f'(K_1 + l_1^a) + \delta'(S_2(S_1, l_1^i)) S'_2(S_1, l_1^i) f(K_1 + e(l_1^a), l_2^a) \\ &+ f'(K_1 + e(l_1^i), l_2^a) e'(l_1^i) \delta S_2(S_1, l_1^i) = 0 \end{aligned} \tag{3}$$

$$f'(K_1 + l_1^a) = w_1 \tag{4}$$

$$f'(K_1 + e(l_1^i), l_2^a) = w_2 \tag{5}$$

The first-order conditions (functions (4) and (5)) can be interpreted as follows: the marginal product of the labor force in agriculture production should be equal to the non-farm wage. Function (3) implies that under the above-mentioned assumptions, the marginal cost of investment at stage I is equal to the wage rate. These first-order conditions can be used to conduct a comparative static analysis of how rural land tenure security affects land investment behavior.

Specifically, if tenure security is strictly exogenous, part of function (3) should be dropped out, and S_1 can be substituted by $S_2\left(S_1, l_1^i\right)$. Then, function (3) can be specified as follows:

$$-(1+r)f'\left(K_1+l_1^a\right)+f'\left(K_1+e\left(l_1^i\right),l_2^a\right)e'\left(l_1^i\right)\delta S_2\left(S_1,l_1^i\right)=0 \quad (6)$$

By bringing functions (4) and (5) into (6), we obtain the following:

$$-(1+r)w_1+w_2e'\left(l_1^i\right)\delta\left(S_1\right)=0 \quad (7)$$

Finding the partial derivatives of function (7) l_1^i, S_1, we obtain the following:

$$e''\left(l_1^i\right)w_2\delta\left(S_1\right)\partial l_1^i+w_2e'\left(l_1^i\right)\delta'\left(S_1\right)\partial S_1=0 \quad (8)$$

Assume $e'(.)>0$, $\delta'(.)>0$, $e''(.)>0$, then the following occurs:

$$\frac{\partial l_1^i}{\partial S_1}=-\frac{e'\left(l_1^i\right)\delta'\left(S_1\right)}{e''\left(l_1^i\right)\delta\left(S_1\right)}>0 \quad (9)$$

Function (9) shows that farming households are more likely to make investments when land tenure security is at a high level. Thus, we propose theoretically that both de jure land tenure security and de facto land tenure security are useful to induce farming households' enthusiasm to make land investments. However, given the fact that several rounds of land tenure reforms were undertaken in rural China in recent years and that potential low efficiency issues may exist, as discussed above, de jure land tenure security is relatively higher than de facto land tenure security. Therefore, we propose that the role of de jure land tenure security is more significant than that of de facto land tenure security.

3. Methodology

3.1. The Dataset

We derived the dataset in this paper from a nationwide rural household survey, conducted in eight provinces of China (Shangdong, Shangxi, Jilin, Zhejiang, Henan, Gansu, Hunan, and Sichuan) by the China Center for Agricultural Policy Research at Peking University from January to July 2013. One of the main purposes of the survey was to investigate the relationship between rural land tenure reform and farming households' livelihood strategies in the context of institutional transformation and the development of rural factor markets.

To obtain reliable and representative samples, a multi-stratified sampling method was applied in the study. In the county sampling stage, the counties were grouped into high, medium, and low groups according to rural income per capital. One county was randomly chosen from each group, and twenty-four county samples were selected. Likewise, in the township sampling stage, the townships were further divided into high and low groups according to the disposable income per capita in the rural regions. Then, 2 townships were randomly selected from each group and 48 townships were chosen. The same sampling method was used in the village sampling stage and 96 villages were selected. A total of 1152 households were selected randomly from a household list provided by the local village committees. A unique sample of plot-level land information was purposely collected for a deeper understanding of the links between land tenure security and farming households' land investments. Specifically, two plots were randomly chosen among those that were planted with wheat, rice, and/or corn for each household in the year before the survey. Only one plot was chosen occasionally when there was one plot for one household. A sample of 2308 plots were matched with 962 farming households in total (see Figure 1 below).

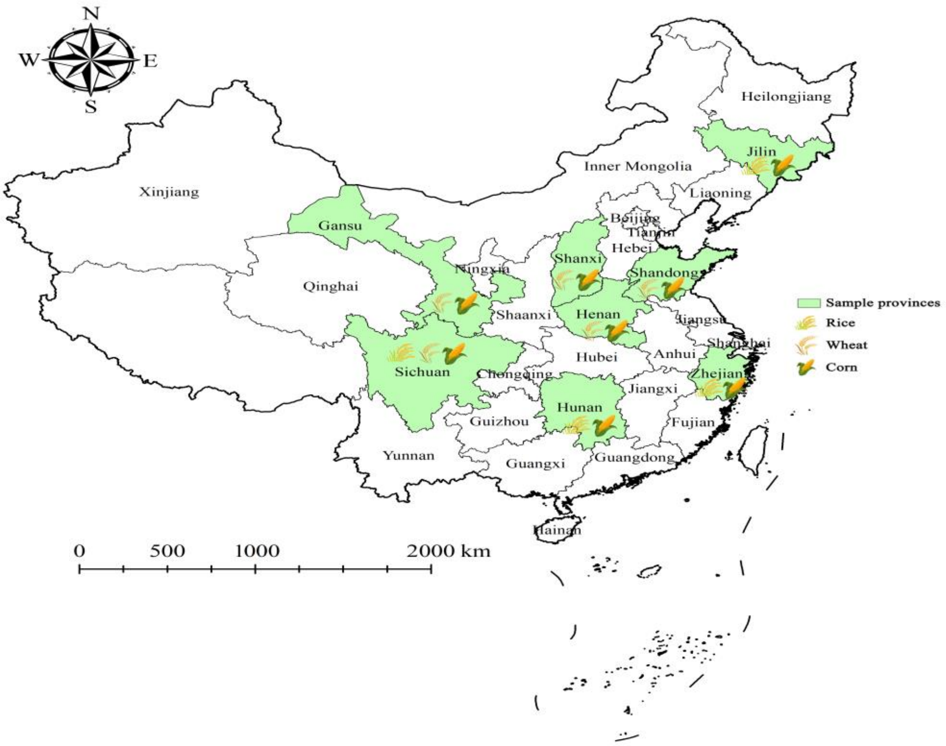

Figure 1. The plot distribution of the eight provinces in China.

Detailed information on village economics, labor market development, arable land endowment, the implementation of land tenure security policies, land certificates held by farming households, land use, and particularly plot-level land characteristics such as fertility, type, irrigation conditions, and so forth were collected. In developing our empirical model, we used a sample of 962 households covering 2308 plots. Plot plantings with wheat accounted for 652, distributed mainly in 5 provinces including Shandong (212 plots), Shanxi (87 plots), Henan (203 plots), Gansu (125 plots), and Sichuan (25 plots). Plot plantings with corn accounted for 1118 plots distributed in the 8 provinces. The remaining 538 plots, which were planted with rice, were distributed in 4 provinces including Jilin (31 plots), Zhejiang (109 plots), Hunan (220 plots), and Sichuan (178 plots) (see Table 1 below).

Table 1. The plot distribution of the eight provinces in China.

Province	Plot Number	Wheat	Corn	Rice
Shandong	404	212	192	-
Shanxi	161	87	74	-
Jilin	274	-	243	31
Zhejiang	244	-	69	109
Henan	408	203	205	-
Gansu	257	125	132	-
Hunan	275	-	55	220
Sichuan	351	25	148	178
Total	2308	652	1118	538

3.2. Model Specification

To investigate the effects of land tenure security on farming households' decisions about their long-term investments in the arable land (the use of organic fertilizer), the model is specified as follows:

$$O_{ij} = a_0 + \sum_{s=1}^{2} \beta_s \cdot T_i^s + \sum_{h=1}^{5} \delta_h \cdot H_i^h + \sum_{l=1}^{8} \gamma_l \cdot L_i^l + \varepsilon_{ij} \quad (10)$$

O_{ij} is the farming household's, i, use of organic fertilizer on the plot, j. T_i is the status of land tenure security of i household, including both the de jure and the de facto status. H is a vector of household characteristics. L is a vector of plot-level land characteristics. ε_{ij} is a random error term. a^0 is a constant term. β_s, δ_h, and γ_l are estimated parameters/co-efficiencies.

We suppose that the land investment behavior of farming households is a two-stage decision-making process. The first step is that the farming households need to determine whether they apply organic fertilizer on their plot. If they decide to use organic fertilizer, they need to decide the amount of organic fertilizer. Therefore, a two-stage estimation method is adopted in the study. The first stage examines whether land tenure security affects the farming households' decision to use organic fertilizer. Considering the dependent variable as a dummy variable (taking the value of either 1 or 0), we ran a Logit model and estimated the marginal effects of independent variables. The second stage is to examine the impact of land tenure security on the amount of organic fertilizer used by the farming households. Since over 80% of farming households do not use organic fertilizer (i.e., application rate = 0), O_{ij} is a mixed distribution of a discrete point 0 and a continuous distribution. Because using ordinary least squares (OLS) procedures to estimate the sample data may cause inconsistency, we adopt the Tobit model to estimate the marginal effects of independent variables.

3.3. Variable Definitions and Descriptive Analysis

Arable land investment: Land investment is usually categorized into short-term and long-term investments, with the harvesting period being one year and over one year, respectively. The former mainly aims at increasing land output. It usually includes the investment of labor, pesticides, and chemical fertilizers. In comparison, the latter mainly aims at protecting and/or improving the quality of arable land [33]. It usually includes land leveling, terrace construction, forestation, and the use of lime, organic fertilizer, and phosphate fertilizer [11,41,42]. According to Gao et al. [43] and Feng et al. [37], we use the application of organic fertilizer as a measurement of long-term investment in arable land. Two specific questions, "Do you use organic fertilizers in your plot?" and "How many organic fertilizers are used in this land?", were used in the questionnaire.

Land tenure security: This variable is indexed from both the de jure and the de facto perspectives. Land titling and issuing land certificates correspondingly is a commonly used legal policy tool for enhancing the level of land tenure around the world [16,44]. We use the holding status of land certificates as the index of de jure land tenure security. It was identified that the land reallocation experience is a widely used and useful index of the de facto land tenure security status [25,40]. Thus, we measure the de facto land tenure security status by asking, "How many times has your arable land been adjusted since the implementation of the second-round land contract policy in 1998?", in the questionnaire.

Control variables: There are four groups of control variables including village characteristics, the characteristics of farming households, the characteristics of plot-level land, and regional dummies. Specifically, the characteristics of farming households include the age and education of the farming household head, risk aversion, the number of off-farm labor in the household, and the status of livestock raised. The impact of age and education is ambiguous. On the one hand, older farmers are more experienced in agricultural production. More educated farmers have more access to the relevant information for land investment. Thus, these two variables are expected to have positive impacts on long-term land investment [11,28]. On the other hand, older farmers are less capable of field management. More educated farmers are more likely to participate in off-farm work. Thus, they are expected to have negative impacts on long-term land investment [32]. Regarding the risk preference variable, we use the dummied status of risk aversion as the index. Risk aversion farmers are less likely to make long-term investment so as to avoid the potential loss of production [45]. Thus, this variable is expected to be negatively correlated with the use of organic fertilizer. Farming households with more off-farm labor have higher opportunity cost and are less likely to make long-term land investments [46]. Livestock is used as an index of family wealth, which is predicted to be positively correlated with the farmers' use of organic fertilizer.

Land characteristics include the distance from the plot to the place of residence, area, soil type, quality, land shape, and irrigation condition. The plots that are further away from the farming households' homes have higher input costs [43]. Thus, we predict it has negative impacts on long-term land investment. The impact of the area is mixed. Investing in a larger area of land may result in a higher return of scale to a certain extent. However, small farming households may be confronted with liquidity constraints from large-scale land management and land investment. The impact of soil type is still ambiguous. It is affected by different types of crops because they have different soil preferences. A higher level of land quality can not only save input costs, but also have higher returns from the investment [47]. Thus, it is predicted to have positive impacts on small farming households' use of organic fertilizer. Farmers are less likely to make long-term investments in land with an uneven surface or irregular shape. However, they are more likely to make investments in fertile plots with good irrigation systems because they can generate higher returns.

Both crop type and regional dummies are introduced in our estimation. The former is used to capture the impact of different growing conditions on the output of crops while the latter is used to capture the impact of different regional characteristics such as the level of economic development and climate conditions.

The definitions of variables and descriptions are shown in Table 2 below.

Table 2. Definitions of variables and descriptive statistics.

Variables	Definitions and Value	Average	Standard Deviation
Independent variable			
Organic fertilizer use	=1 if households had used organic fertilizer; =0 otherwise.	0.194	0.395
The magnitude of organic fertilizer use	Ton/ha	1.933	5.822
Dependent variable			
Land certificate	=1 if households hold land certification; =0 otherwise.	0.672	0.470
Frequency of land adjustment	Number of land adjustment	1.146	2.749
Household characteristics			
Age of household head	Age of the head of household (years)	53.487	9.826
Education of household head	Years of education of the household head (years)	6.960	3.128
Risk aversion	=1 if household head is risk aversion; =0 otherwise.	0.478	0.233

Number of off-farm employment	The number of family members who are engaged in the off-farm work	1.472	1.052
Livestock	=1 if the household raises livestock; =0 otherwise.	0.559	0.496
Land characteristics			
Distance	The distance from land to residential place (km)	0.627	0.589
Area	The land area cultivated (hectare)	0.175	0.484
Quality level (high)	=1 if the soil quality of cultivated land is high; =0 otherwise.	0.401	0.490
Quality level (medium)	=1 if the soil quality of cultivated land is medium; =0 otherwise.	0.413	0.493
Quality level (low)	=1 if the soil quality of cultivated land is low; =0 otherwise	0.185	0.389
Soil type (sand)	=1 if the soil type belongs to sand; =0 otherwise.	0.243	0.429
Soil type (loam)	=1 if the soil type belongs to loam; =0 otherwise.	0.374	0.484
Soil type (clay)	=1 if the soil type belongs to clay; =0 otherwise.	0.383	0.486
Flat	=1 if the land is flat; =0 otherwise.	0.741	0.438
Irrigation	=1 if the land can receive enough irrigation;=0 otherwise.	0.601	0.490
Crop type			
Wheat	=1 if the land is planted with wheat; =0 otherwise.	0.282	0.450
Corn	=1 if the land is planted with corn; =0 otherwise.	0.484	0.500
Rice	=1 if the land is planted with rice; =0 otherwise.	0.233	0.423
Provincial dummies			
Shangdong	=1 if the household resides in Shangdong Province; =0 otherwise.	0.175	0.380
Shan'xi	=1 if the household resides in Shan'xi Province; =0 otherwise	0.070	0.255
Jilin	=1 if the household resides in Jilin Province; =0 otherwise.	0.119	0.324
Zhejiang	=1 if the household resides in Zhejiang Province; =0 otherwise.	0.077	0.267
Henan	=1 if the household resides in Henan Province; =0 otherwise.	0.177	0.382
Gansu	=1 if the household resides in Gansu Province; =0 otherwise.	0.111	0.315
Hunan	=1 if the household resides in Hunan Province; =0 otherwise.	0.119	0.324
Sichuan	=1 if the household resides in Sichuan Province; =0 otherwise.	0.152	0.359

Table 3 shows the land tenure security status and the use of organic fertilizer by farming households. It can be found that 19.37% of 2308 land plots were applied with organic fertilizer, with an average of 1.93 tons per ha. Intuitively, both de jure land tenure security and de facto land tenure security are relevant to the use of organic fertilizer at the plot-level. On the one hand, farming households who were issued land certificates were more likely to use organic fertilizer in their plots than those who were not issued land certificates. More specifically, organic fertilizer was used in 22.37% of the plots with certificates, which was 9.16% higher than those without land certificates. The average amount of organic fertilizer used in the plots with land certificates hit 2.33 tons per ha, which was 1.20 tons more than those used in the plots without land certificates. This indicates that legal land tenure motivated the farming households to use organic fertilizer on their plots.

Table 3. Land tenure security status and use of organic fertilizer by farming households.

	The Number of Plots	The Use of Organic Fertilizer	
		Use Rate (%)	Use Amount (ton/ha)
Total sample	2308	19.37	1.93
The status of holding land certificate			
Yes	1551	22.37	2.33
No	757	13.21	1.13
The frequency of land adjustment			
0	1315	21.29	2.08
[1, 3]	879	17.63	1.94
>3	114	10.53	0.14

In addition, it can also be found that the farming households who experienced more frequent land adjustments were less likely to use organic fertilizer. Likewise, this reflected that de facto land tenure security might be positively correlated with the use of organic fertilizer by farming households. This can be further demonstrated by the fact that among the 1315 farming households without land adjustment experiences, 21.29% used organic fertilizer, which was 3.66% higher than that among 879 farming households with their land adjusted between 1 and 3 times. Furthermore, it was 10.76% higher than the 114 farming households that experienced land adjustments more than three times. It was the same case for the average use amount of organic fertilizer. Farming households without land adjustment experiences used 2.08 tons of organic fertilizer per ha, which was 0.14 tons and 1.94 tons higher than the other two types of farming households with land adjustment experiences, respectively.

4. Empirical Analysis

4.1. Estimation Results

Table 4 shows the estimation results. Generally, the p-values show that these independent variables are significant at a reasonable significance level. The signs of estimated coefficients of the main independent variables are consistent with our expectations. Regarding the impact of land tenure security on the use of organic fertilizer by farming households, de facto land tenure security has a significant impact on farming households' use of organic fertilizer. Specifically, the results of the first stage estimation show that the coefficient of de facto land tenure security is significantly negative. It indicates that farming households with more experiences of land adjustments are less likely to use organic fertilizer than those with fewer experiences of land adjustments. This finding is similar with those made by Ma et al. (2013), Zheng (2024), and Campos (2023), who demonstrate that secure land tenure is positively relevant with farmers' land investments[28,29,31]. A higher level of de facto land tenure security is more likely to motivate farming households to use organic fertilizer. A similar impact of de facto land tenure is also found in terms of the magnitude of organic fertilizer use. The farming households with and/or without holding a land certificate do not show significantly different consumption behaviors of organic fertilizer. A possible explanation is that the level of de jure land tenure security is so high in rural China that its impact on the use of organic fertilizer by farming households is similar. Another explanation may be that the implementation of relevant policies on de jure land tenure security is not enforced sufficiently by policy makers. From this perspective, enforcing effective policy implementation is of crucial importance.

Table 4. The two-stage estimation results.

Key Variables	Logit		Tobit	
	Coefficient	Marginal Effect	Coefficient	Marginal Effect
Land certificate	−0.1053 (0.1420)	−0.0134	−0.5113 (1.2407)	−0.1043
Frequency of land adjustment	−0.0755 ** (0.0301)	−0.0096	−0.7872 *** (0.2620)	−0.1606
Household characteristics				
Age	0.0162 ** (0.0064)	0.0021	0.1310 ** (0.0561)	0.0267
Education	0.0754 *** (0.0214)	0.0096	0.5497 *** (0.1907)	0.1122
Risk aversion	−0.6603 ** (0.2623)	−0.0841	−5.7210 *** (2.1683)	−1.1675
Number of off-farm employment	−0.1727 *** (0.0615)	−0.0220	−1.3591 *** (0.5184)	−0.2773
Livestock	1.7153 *** (0.1699)	0.2185	14.7166 *** (1.4364)	3.0031
Land characteristics				
Distance	−0.3658 *** (0.1219)	−0.0466	−2.9198 *** (1.0918)	−0.5958
Area	−0.6555 (0.4805)	−0.0835	−6.8087 (4.3041)	−1.3894
Quality level (high)	0.3800 ** (0.1919)	0.0484	2.7302 * (1.5700)	0.5571
Quality level (medium)	0.3128 * (0.1780)	0.0398	2.4754 * (1.4587)	0.5051
Soil type (loam)	−0.6757 *** (0.1756)	−0.0861	−5.1413 *** (1.4536)	−1.0492
Soil type (clay)	−0.2548 (0.1679)	−0.0324	−1.7982 (1.3480)	−0.3669
Flat	−0.3106 ** (0.1512)	−0.0396	−2.9535 ** (1.2593)	−0.6027
Irrigation	−0.2676 * (0.1437)	−0.0341	−0.7693 (1.2040)	−0.1570
Crop type				
Corn	−0.1662 (0.1670)	0.0212	−0.9566 (1.4507)	−0.1952
Rice	−0.7935 *** (0.2432)	−0.1011	−8.3392 *** (2.0656)	−1.7017
Provincial dummies	Controlled	Controlled	Controlled	Controlled
Constant	−2.8491 *** (0.5323)		−26.7059 *** (5.1210)	
Observation	2308		2308	
Pseudo R*	0.1939		0.0857	
Log pseudolikelihood	−911.0108		−2381.4978	

Notes: Values in parentheses are robust standard errors; ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

Regarding farming households' characteristics, both the age and education level of the household heads have significantly positive impacts on the use of organic fertilizer on their land. This means that farming households are more likely to use organic fertilizer more if the household heads are older or more educated. A possible explanation is that the older and more educated household heads are more experienced in agricultural cultivation and usually pay more attention to the protection and improvement of soil quality. Therefore, they are more likely to apply organic fertilizer on their land. In addition, farming households are less likely to use organic fertilizer because they are more risk averse. The risk averse farming households are less interested in land investment. The number of off-farm workers in the household is found to be negatively correlated with households' long-term investments in the land. In other words, in a household where there are more family members who are engaged in off-farm jobs, it is less likely for the household head to use organic fertilizer or use it more on their land because it is laborious to collect manure and apply it to the land. On the one hand, if a farming household has more off-farm family members, there are higher opportunity costs of applying organic fertilizer on their land. Therefore, the farming household may be reluctant to use organic fertilizer. On the other hand, farming households might face a shortage of on-farm workers, which limits their ability to make investments in the land. Livestock has a significant and positive effect on the long-term investment of farming households. The regression results show that the probability of livestock farming households is 21.85% higher than that of households without livestock farming, and the amount of fertilizer application is 3.00 tons more per ha. One possible explanation is that households with livestock farming have abundant manure compared to those without. Applying manure as an organic fertilizer on rural land can not only improve land quality but also save the cost of manure disposal.

Among the variables of land characteristics, the signs of coefficients are consistent with our expectations. The results show that both the distance and the area have negative effects on the use of organic fertilizer. This indicates that a farming household is less likely to use organic fertilizer or use it more if the land is far from their home or the land is less flat. One possible explanation is that the cost of transporting organic fertilizer rises as the distance between the land and the home increases, thereby causing a higher cost of applying organic fertilizer. In addition, land quality and type of land also affect long-term investments on rural land by farming households to a certain extent. The regression results show that farming households are more likely to apply organic fertilizers on high-quality and medium-quality land than on low-quality land. The application amount of organic fertilizer tends to be higher on high-quality and medium-quality land because high-quality land tends to have better soil fertility, and correspondingly the investment in high-quality land can have higher returns. Therefore, farming households are more willing to apply organic fertilizers on sandy soil than clay soil or loam soil because the loam soil and clay soil are less permeable than sandy soil, whereas organic fertilizers can leach in sandy soil more readily and effectively.

4.2. Robustness Check

To double-check the reliability and consistency of the above estimation results, two robustness checks were conducted. The first one is undertaken with three steps. First, a linear probability model (LPM) is used to examine whether land tenure security affects the application of organic fertilizer by farming households. Second, OLS estimation is used to examine whether land tenure security affects the amount of organic fertilizer used by farming households. Finally, given the fact that the rented land does not have land certificates, selection bias may exist in the previous empirical analysis. In order to deal with this issue, we use the ratio of land certificates as a proxy for de jure land tenure security. The estimation results are shown in Table 5 below. Both the influence direction and significance of the key explanation variables are consistent with those in Table 4. This indicates that the previous estimation results are reliable to a large extent.

Table 5. The results of the first robustness check.

Variables	LPM	OLS	Marginal Effect Obtained From Logit Estimation	Marginal Effect Obtained From Tobit Estimation
Key variables				
Land certificate	−0.0061 (0.0173)	0.1288 (0.2386)	-	-
Ratio of land certificate	-	-	−0.0001 (−0.0002)	−0.0003 (0.0030)
Frequency of land adjustment	−0.0082 *** (0.0017)	−0.0649 *** (0.0234)	−0.0095 ** (−0.0039)	−0.1592 *** (0.0540)
Household characteristics				
Age	0.0018 ** (0.0008)	0.0100 (0.0132)	0.0021 ** (0.0008)	0.0266 ** (0.0115)
Education	0.0092 *** (0.0027)	0.0644 (0.0440)	0.0096 *** (0.0008)	0.1128 *** (0.0387)
Risk aversion	−0.0906 *** (0.0326)	−1.2643 ** (0.5016)	−0.0838 ** (0.0332)	−1.1625 ** (0.4420)
Number of off-farm employment	−0.0209 *** (0.0074)	−0.2057 * (0.1140)	−0.0221 *** (0.0078)	−0.2781 *** (0.1059)
Livestock	0.1918 *** (0.0164)	1.9772 *** (0.2085)	0.2183 *** (0.2068)	3.0002 *** (0.2907)
Land characteristics				
Distance	−0.0401 *** (0.0130)	−0.2735 (0.2318)	−0.0469 *** (0.0155)	−0.5985 *** (0.2225)
Area	−0.0105 (0.0088)	−0.2266 * (0.1340)	−0.0822 (0.0614)	−1.3805 (0.8755)
Quality level (high)	0.0449 ** (0.0225)	0.5519 * (0.2933)	0.0485 ** (0.0243)	0.5598 * (0.3198)
Quality level (medium)	0.0398 * (0.0222)	0.4777 (0.2967)	0.0395 * (0.0243)	0.5029 * (0.2973)
Soil type (loam)	−0.0843 *** (0.0222)	−0.6876 ** (0.3237)	−0.0861 *** (0.0221)	−1.0509 *** (0.2958)
Soil type (clay)	−0.0325 (0.0216)	−0.2017 (0.2773)	−0.0325 (0.0213)	−0.3680 (0.2742)
Flat	−0.0442 ** (0.0199)	−0.6354 ** (0.2880)	−0.0396 ** (0.0192)	−0.6025 ** (0.2571)
Irrigation	−0.0333 * (0.0199)	0.1120 (0.3031)	−0.0338 * (0.0182)	−0.1577 (0.2463)
Crop type				
Corn	−0.0148 (0.0185)	0.1538 (0.2924)	−0.0206 (0.0213)	−0.1910 (0.2956)
Rice	−0.1352 *** (0.0345)	−2.4766 *** (0.5173)	−0.1005 *** (0.0307)	−1.6969 *** (0.4227)
Provincial dummies	Controlled		Controlled	Controlled
Constant	0.0573	0.4582		

	(0.0677)	(1.1900)		
Observation	2308	2308	2308	2308
F	22.37	11.76		
R *	0.1609	0.1081		
Pseudo R *			0.1937	0.0857
Log pseudolikelihood			−911.2257	−2381.5741

Notes: Values in parentheses are robust standard errors; ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

The second round of the robustness check was conducted by substituting the dependent variable of organic fertilizer use with the investment in the construction of the facility (such as land leveling, digging wells, maintaining canals and terracing, and so forth). The reasons are twofold. First, the use of organic fertilizer does not mean that it is sustainable indefinitely. For instance, the overuse of quick-acting organic fertilizer and/or compound fertilizer can damage the soil structure and lower the soil quality. Second, the construction of facility infrastructure in arable land is featured as a large amount of long-term investment. Therefore, the new variable is a perfect index for measuring the long-term investment in sustainable land. In our analysis, it specifically refers to the investment activities initiated by the farming households themselves, excluding those investments made by the local government with public expenditure.

The descriptive statistics of the possible linkages between land tenure security and small farming households' private investments in the construction of facility infrastructure are shown in Table 6 below.

Table 6. Land tenure security and farming households' investments in construction of facility infrastructure.

	Plot Number	**Percentage of Investment (%)**
Total observation	2308	6.20
Whether they hold a land certificate or not		
Yes	1551	7.03
No	757	4.49
Experienced land adjustment frequency		
0	1315	8.06
(0, 3]	879	4.21
>3	114	0.00

We can find that the plots on which farming households made investments in the construction of facility infrastructure accounted for 6.20%. Intuitively, the farmers were more likely to make investments in the construction of facility infrastructure on the plots with land certificates. In other words, the percentage of investments in the construction of facility infrastructure was 7.03% among the plots with land certificates. It was 2.54% higher than that invested in the plots without land certificates. Similarly, small farming households were less likely to make investments in the construction of facility infrastructure on the plots with more frequent land adjustments. For instance, the plots without land adjustment experiences received the highest investments (8.06%) among all plots.

Based on the observations mentioned above, we further conducted the second round of robustness checks. Technically, we first used the linear probability model (LPM) to examine the impact of land tenure security on the investment in the construction of facility infrastructure. Second, as we discussed previously, there is usually no land use certificate and/or other documents for the rented plots. Thus, there might be potential selection bias in our estimation. To handle this issue, the percentage of land with usage certificates is used as a proxy for de jure land tenure security. The Logit estimation results are shown in Table 7. The coefficients of the key variables are consistent with those previously obtained. In other words, de facto land tenure security has significant and positive effects on the investment in the construction of facility infrastructure. Thus, the previous estimation results are reliable to a large extent.

Table 7. The estimation results of the second robustness check.

Variables	General Estimation	Robustness Check	
	Logit (Marginal Effect)	LPM	Logit (Marginal Effect)
Key independent variables			
Land use certificate and/or other documents	0.0254 * (0.0133)	0.0202 (0.0124)	
Percentage of land use certificate and/or other documents			0.0003 ** (0.002)
Frequency of land adjustment	−0.0170 *** (0.0061)	−0.0018 * (0.0010)	−0.0170 *** (0.0061)
Household characteristics			
Age of household head	0.0023 *** (0.0006)	0.0021 *** (0.0006)	0.0023 *** (0.0006)
Education of household head	0.0004 (0.0017)	0.0005 (0.0017)	0.0003 (0.0017)
Level of risk aversion	−0.0065 (0.0195)	−0.0135 (0.0179)	−0.0072 (0.0195)
Number of household members engaged in off-farm work	0.0105 ** (0.0045)	0.0111 ** (0.0054)	0.0111 ** (0.0045)
Livestock	−0.0094 (0.0122)	−0.0073 (0.0117)	−0.0109 (0.0123)
Plot characteristics			
Distance from home to the plot	0.0062 (0.0083)	0.0108 (0.0107)	0.0067 (0.0083)
Plot area	0.0463 *** (0.0122)	0.0869 *** (0.0113)	0.0420 *** (0.0116)
High-quality soil	−0.0067 (0.0153)	−0.0104 (0.0140)	−0.0070 (0.0154)
Medium-quality soil	0.0085 (0.0149)	0.0101 (0.0135)	0.0077 (0.0150)
Loam	−0.0145 (0.0129)	−0.0198 (0.0152)	−0.0154 (0.0129)
Clay	−0.0316 ** (0.0127)	−0.0372 *** (0.0138)	−0.0325 ** (0.0128)
Land leveling	−0.0078 (0.0127)	−0.0216 * (0.0124)	−0.0077 (0.0126)
Irrigation	0.0940 *** (0.0155)	0.0846 *** (0.0118)	0.0928 *** (0.0154)
The dummied crop type			
Corn	−0.0026 (0.0124)	−0.0002 (0.0127)	−0.0031 (0.0124)
Rice	0.0122 (0.0239)	0.0148 (0.0197)	0.0109 (0.0238)
Provincial dummy	YES	YES	YES

Observation	2308	2308	2308
Pseudo R^2	0.1698		0.1718
Log pseudolikelihood	−445.1400		−444.1025
F		7.44	
R^2		0.086	

Notes: Values within parentheses are robust standard errors; ***, **, and * indicate statistical significance at 1%, 5%, and 10% levels, respectively.

5. Conclusions and Discussions

The essential role of land tenure security in sustainable land use and food security was identified [48]. This study has empirically examined the impact of both de jure and de facto land tenure security on the use of organic fertilizer by farming households at the plot-level in China with the data collected from 2308 land plots from Shandong, Shaanxi, Jilin, Zhejiang, Henan, Gansu, Hunan, and Sichuan Provinces. The estimation results indicate that de jure tenure security has no significant effect on farmers' use of organic fertilizer. In contrast, de facto tenure security has a significant effect. That is, farming households with higher levels of de facto land tenure security are more likely to apply organic fertilizer on their plots than those with insecure de facto land tenure security households. Our findings are not consistent with those of Reerink and Van Gelder (2010), Hosaena et al. (2016), and Nakamura (2016), who identified the important role of perceived land tenure security in the decision-making of farmers' land use [38,49,50]. There is no doubt that land tenure security plays an essential role in motivating farming households to make sustainable land investments [11]. However, there is still no consensus underlying the debate on which dimension of land tenure security is the most important: de jure or de facto? Indeed, it was identified that the impact of various dimensions of land tenure security depend mainly on the national institution environment [51]. More specifically, the condition that affects de facto land tenure security differs from that of de jure land tenure security in developing economies like China, where the design of formal land tenure institutions by the central government is sufficient, but its implementation is poor at a lower level of society [20]. This means that despite the fact that the security level of de jure land tenure is high, land users are usually provided with limited official property rights and formal protection from legitimacy. From this point of view, customary land tenure may be even more important than de jure land tenure because it can enhance de facto land tenure security [48,52,53]. This may explain why the coefficient of de jure land tenure security is not statistically significant in our analysis because it is relatively high after several rounds of land tenure security reforms in China since 1978 [20].

Nevertheless, the land tenure insecurity issue is not unique to China. It exists widespread among many African countries such as Nigeria and Ethiopia, Latin American countries such as Nicaragua, and Central and Eastern European countries [31,54,55]. Given that arable land was and is still the most fundamental resource for rural households' livelihoods, and that secure tenure is essential for encouraging rural households to make sustainable land investments, land tenure reform has long been a primary focus in many countries' political and agrarian reforms. However, due to the various sources of insecurity stemming from ambiguous ownership, land adjustment, and land expropriation [33], land right and access to land have become significant sources of conflict, leading to ineffective land use [54]. Thus, providing rural households with a high level of tenure security through land tenure reform is essential for a central government's policy making [56]. This has led to the development of land titling as an important strategy for coping with land tenure insecurity in many countries. The potential rationale is that land registration can fix the boundaries of land parcels and identify the holder of the land, providing a basis for legal protection and a structure for resolving land conflicts [55]. China is no exception. The central government of China has made tremendous efforts in conducting a massive scale of land registration programs and carried out the relevant reforms such as the "Three Rights Separation" (Sanquan Fenzhi) reform and the pilot reform "Second Round Extension" (Erlun Yanbao) for the arable land in three provinces (Anhui, Hunan, and Guangxi) since 2011. While the legal land tenure institution can secure de jure tenure security, its complex interactions with local political, economic, social, political–economic, and ecological dynamics may generate conflicts and insecurities. Many empirical studies across African countries have also found that the role of land registration in reducing land tenure insecurity and conflicts is modest [54]. The main reason is that the procedure of land registration usually ignores multiple, competing and overlapping rights to create rent-seeking opportunities for rural elites and to maintain the existing inequalities in land allocation [57]. As a result, an ineffective legal land tenure policy is inevitable. Thus, a careful diagnosis of the relevant institutional environment should be conducted before a policy is implemented. More importantly, a deep understanding of the generation mechanism of land tenure insecurity is essential because the mechanism can facilitate understanding the influence of land tenure (in)security on the decision-making of rural households' land use.

Based on the above research findings and discussions, we make the following policy recommendations. First, it is necessary to maintain land tenure security in order to induce landholders with sustainable land investment enthusiasms. Specifically, it is vital to implement legal land tenure policies strictly. This is particularly the case for the implementation of relevant provisions about land adjustment in rural China under the Land Contract Law since our empirical evidence shows that land adjustment has significant and negative impacts on farming households' land investments. Second, it is of crucial importance to improve de facto land tenure security because it has significant and positive effects on farmers' use of organic fertilizer on their land, according to our research. Thus, it is very important to improve the implementation efficiency of land tenure policies to protect farmers' land use. For instance, local governments should formulate feasible guiding documents to facilitate the issue of land certificates to farmers so that the protection of legal land tenure can be strengthened, and that the land use of farming households will not be interfered with by third parties. Finally, we have found that at the plot-level, the parcel area has significant and positive impacts on the land investment behaviors of farming households. This implies that the characteristics of land parcel matter for the land use of farming households. Therefore, we should pay more attention to the land fragmentation issue and carry out projects centered on land consolidation in farming areas.

It is notable to point out that there are some limitations in our study, which can lead to future research. First, since the adverse effect of land tenure insecurity on sustainable land investment was identified by many earlier studies, why it still occurs in many regions both in rural China and in many other developing countries was not discussed systematically in our study. The extant literature has made explanations in terms of village geography[58], rent-seeking incentives of village cadres[36], the ambiguity of land tenure institutions[53], and so forth. In the context of rural China, the central government is currently conducting a new round of pilot reform named "Second Round Extension for Contract". It aims at securing land tenure by extending the cultivation period for another 30 years. Given that off-farm immigration has been prevailing in recent years, the link between land and population may change. Correspondingly, the generation mechanism of land tenure (in)security may also change. Therefore, future studies should examine the internal generation mechanism of land tenure insecurity in rural China, focusing particularly on the impact of the latest "Second Round Extension for Contract" policy. Second, our study has not examined the comprehensive impact of land tenure security on long-term land investment by smallholder farmers from a fully triple perspective due to data constraints. Future research can include de jure, de facto, and the perceived tenure security together in the empirical analysis.

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