

Article

Does E-Commerce Participation among Farming Households Affect Farmland Abandonment? Evidence from a Large-Scale Survey in China

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Abstract: Reducing farmland abandonment is crucial for food security. While the association between e-commerce proliferation and farmland abandonment at the village level has been discussed, the correlation at the farming household level remains unexplored. Utilizing 2020 survey data from 3831 rural households across 10 Chinese provinces, this study develops an “e-commerce–household–farmland abandonment” framework to explore the co-occurrence of e-commerce engagement with farmland abandonment, using econometric models. The findings reveal that e-commerce engagement significantly increases farmland abandonment, with implicit and explicit rates rising by 10.3% and 28.5%, respectively. It also shifts household incomes from planting to forestry, animal husbandry, and fisheries, leading households to reallocate labor away from agriculture, thereby intensifying abandonment. However, land transfer can alleviate this co-occurrence. This study also explores the variation in the association between e-commerce participation and farmland abandonment in relation to agricultural subsidies, economic development, and the presence of family farms. By elucidating the dynamics at the household level, this research offers fresh perspectives for developing countries to safeguard food security by curbing farmland abandonment.

Keywords: farming households; e-commerce participation; farmland abandonment



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1. Introduction

In the 21st century, humanity faces three main challenges, two of which are directly related to food: “Matching the rapidly changing demand for food from an increasingly larger and more affluent population to its supply” and “Ensuring that the world’s poorest people are no longer hungry” [1]. To overcome these challenges, the United Nations’ post-2015 Sustainable Development Agenda has identified one of the critical indicators for the 17 Sustainable Development Goals set for 2030—that is, hunger eradication [2]. However, since 2014, the number of people experiencing food insecurity has been increasing. As per the Global Food Crisis Report 2020, released by the Global Food Crisis Network, 135 million people across 55 countries and regions faced severe food insecurity up until the end of 2019. If this trend persists, achieving the zero hunger and poverty goals by 2030 will be impossible [3]. Hence, ensuring a sufficient food supply for the global population continues to be a major challenge worldwide.

Sufficient cultivated land is a well-recognized factor in ensuring food security [4]. However, with gradually increasing urbanization, the abandonment of cultivated land has emerged as a critical impediment to the world’s economic development [5]. Early farmland abandonment occurred in developed countries such as Europe, the United States, Australia, and Japan, and it is also becoming increasingly serious in regions like China, Latin America, and Southeast Asia [6]. This phenomenon has exacerbated the challenge of addressing the global food security crisis. Consequently, investigating the reasons for

the abandonment of arable land has become a focal point of research in disciplines like geography and economics. Current studies have focused predominantly on the migration of labor force from rural to urban areas [7], the reduction in net income from land use [8], and the enhancement and commercialization of agricultural technology [9]. However, few of the studies have investigated the co-occurrence of farming households' participation in e-commerce with farmland abandonment.

The literature on the co-occurrence of farming households' e-commerce participation with farmland abandonment can be categorized into two types: (1) Direct studies, in which, to our knowledge, only one study by Wang et al. [10] discussed the co-occurrence of rural e-commerce proliferation with farmland abandonment by farming households. According to these studies, the spread of rural e-commerce helps curb farmland abandonment, which is attributable to the return of agricultural labor to rural areas, the development of rural industries, and the establishment of a robust land transfer system. Hence, these studies lay a robust foundation for our exploration of the co-occurrence of e-commerce participation by farming households with farmland abandonment. (2) Indirect studies have, instead, discussed the impact of e-commerce development on agriculture, rural areas, and farmers, which can be summarized as follows. The first is the impact of e-commerce development on farmers' income, representing a contentious issue in current research. Some scholars argue that e-commerce significantly boosts the average income of farmers [11,12], but others believe that an inverted U-shaped relationship exists between e-commerce and farmers' income [13]. The second most widely discussed topic is the impact of e-commerce on rural industrial structure [14,15]. Some researchers, including Tao et al. [16], hold the belief that e-commerce in rural areas optimizes the non-agricultural industry structure and promotes a shift to tertiary industries at the county level. The third is the effect of e-commerce on agricultural production [17,18], which remains controversial. Some scholars believe that e-commerce promotes agricultural production by enhancing the market participation of agricultural products and optimizing production strategies [19]; however, others believe that e-commerce squeezes the space available to agricultural production by creating more non-agricultural job opportunities [20].

The existing literature provides a solid foundation for the successful conduct of our study; however, several issues remain to be resolved. (1) Quantitative research on the relationship between rural e-commerce and farmland abandonment remains relatively scarce. Many developing countries' governments and international NGOs have considered developing rural e-commerce as a promising approach to improve rural economies, and the Chinese government has identified rural e-commerce development as a key driver of rural revitalization. Increasing farmers' income is one of the goals of rural revitalization policies. Whether this will affect farmland abandonment has become a new perspective and issue for us to understand rural revitalization. The impact of the internet and information technology on farmland abandonment has also been discussed by various scholars. For example, Deng et al. have discussed the impact of internet use by rural households on farmland abandonment [21], which serves as a reference for our research. (2) Limited studies have examined the co-occurrence of e-commerce participation from the micro-perspective of farming households with farmland abandonment. Wang et al. [10] have discussed the impact of rural e-commerce proliferation on farmland abandonment from a broader perspective, providing a robust basis for our study; however, farmland abandonment is the result of a nested-structure activity involving plots, farming households, and villages [22]. Exploring the co-occurrence of farming households' e-commerce participation with farmland abandonment holds a significant value. (3) Farmland abandonment has not been comprehensively and precisely estimated yet. Though a consensus on the concept of farmland abandonment has not been established, most scholars agree with its division into explicit and implicit forms. Explicit abandonment refers to deliberately leaving land fallow and unproductive, whereas implicit abandonment refers to under-utilization of the land as a result of inefficient and extensive management [23]. Among these, the implicit abandonment of farmlands has been largely overlooked. Theoretically,

implicit abandonment could evolve into persistent abandonment [24]; however, in practice, under strict farmland protection policies, land sentiment, and in the pursuit of agricultural subsidies, some farming households tend to engage in extensive farming practices, which lead to implicit abandonment. Quantitative studies focusing on implicit abandonment are scarce because of the difficulty in its quantification. Additionally, explicit abandonment by farming households might have been underestimated. Moreover, its frequency is rare owing to China's strict farmland protection policies and the application of remote sensing technology in the country. In some cases, farmers often choose to underreport or not report explicit farmland abandonment to avoid penalties. Thus, existing studies relying on survey data to gather information on explicit abandonment by farmers may underestimate the extent of explicit farmland abandonment. To address the aforementioned issues, this study explores the co-occurrence of Chinese farming households' participation in e-commerce with farmland abandonment, with a focus on distinguishing between explicit and implicit farmland abandonment. The reasons for choosing Chinese farming households as the research subject are primarily the following: (1) In China, the experimental conditions for observing the relationship between rural e-commerce usage and farmland abandonment from the micro-perspective of farming households are excellent. Historically, China is an agriculture-dominated country, with its average rural households possessing only 0.38 hectares of farmland, which is below the global average level [25]. This makes it a typical country with a significant contradiction between its population and the available land resources [19]. In order to ultimately achieve food security, rural development, and prosperity for farmers, China implemented the e-commerce demonstration county policy in 2014. Undoubtedly, China's e-commerce participation and the situation of farmland abandonment provide favorable conditions for our study. (2) Small-scale farmers (smallholders) are the mainstay of China's agricultural production and are involved in decision making for land use. Since the implementation of the household responsibility system, farming households have become the basic unit of land use in China. According to data from China's third national agricultural census, smallholders account for over 98% of agricultural operators and manage 70% of the total cultivated land area. Furthermore, farming households serve as the main decision-making entity for choosing land use methods. These data suggest that farming households hold a vital position in China's agricultural production and are pivotal in decisions regarding household land use, providing a practical basis for discussing the co-occurrence of e-commerce participation with farmland abandonment from the perspective of farming households.

Therefore, this study utilizes data from a survey of 3831 farming households across 10 provinces in China in 2020 to discuss the relationship between farming households' e-commerce participation and farmland abandonment. This approach includes the following queries: (1) Is there a co-occurrence between the e-commerce participation of farming households and] farmland abandonment? This question pertains to both explicit and implicit farmland abandonment. (2) What associations exist between farming households' e-commerce participation and farmland abandonment? What specific patterns or correlations can be observed? (3) In what aspects can the heterogeneity of the co-occurrence between the e-commerce participation of farming households and farmland abandonment be observed?

The main contributions of this study are as follows: (1) It explores the nature and patterns of the association between e-commerce participation by farming households and farmland abandonment from a micro-perspective, thereby contributing to the literature on the relationship between rural e-commerce and farmland abandonment. (2) It measures explicit and implicit abandonment through calculations rather than direct inquiries, thereby offering a more precise and multidimensional measurement of farmland abandonment among farming households. (3) It utilizes the latest national survey data of 2020 for a statistical analysis, thus providing data support to analyze the extent of e-commerce participation among Chinese farming households at present, the current state of farmland abandonment, and their interrelation. (4) This study presents robust conclusions on the relationship between e-commerce and land use changes from the perspective of farming

households, which are crucial for ensuring food security in developing countries like China. Given the higher prevalence of farmland abandonment in developed countries, the findings of this study might also be applicable to developed nations.

2. Theoretical Analysis Section

The nature and patterns of the association between e-commerce participation by farming households and farmland abandonment is complex. Traditional research considers farmers to be rational, following Schultz's viewpoint that rational farmers allocate labor and land resources to maximize income [26]. However, modern economics and sociology suggest that farmers' decision making is not solely rational but also influenced by social, political, and other factors [27]. Considering the universal applicability and simplicity of rational decision-making theory, this study primarily analyzes rural households' land use decisions based on the rationality assumption. Evidently, changes in land use stem from variations in the potential uses of land and their comparative returns [28]; if the returns from cultivation are lower than those from other activities, farmers tend to shift their labor to other areas. In the case of challenges or uncertainties in implementing alternatives like land transfer, contracting out cultivation, or switching to different crops, farmers may opt to abandon their farmland [29]. Thus, in this study, nature and patterns of the association between e-commerce participation by farming households and farmland abandonment have been analyzed from three dimensions, namely, planting income, agricultural labor, and land transfer. For these analyses, this study establishes a theoretical analysis framework (Figure 1).

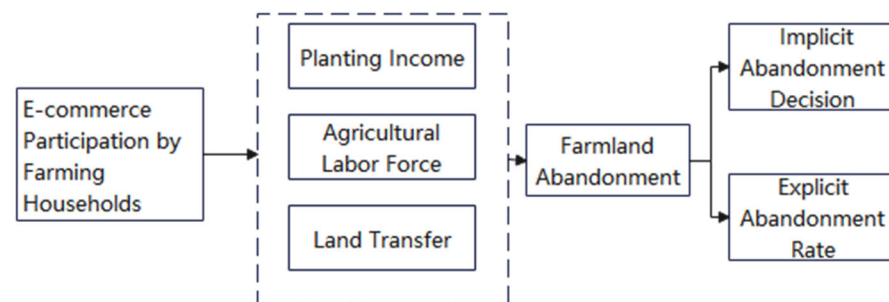


Figure 1. Theoretical framework.

As shown in Figure 1, farming households' participation in e-commerce might reduce planting income [20], thereby exacerbating farmland abandonment. It is generally believed that farming households' e-commerce participation increases product sales by enhancing information gathering capabilities, which contribute to increasing the household income [30]. Conversely, Zhang [20] asserted that the increased income achieved through households' e-commerce participation is mostly derived from non-agricultural sources, potentially "crowding out" the agricultural operating income (including income from crop cultivation). Some studies have documented the increase in the opportunity cost of farming as the fundamental cause of farmland abandonment [31], which refers to the planting income being lower than other sources of income. For example, with increasing urbanization and industrialization in China, the degree of diversification in Chinese farming households' livelihoods has increased. This implies that agriculture is no longer the main means of subsistence for these households [32]. This shift in income source has led to farmland abandonment in some areas [33]. Therefore, farming households' e-commerce participation might suppress planting income, leading to an increase in farmland abandonment.

Furthermore, participation in e-commerce leads to changes in agricultural labor in farming households [14], which, in turn, affect farmland abandonment. How e-commerce participation affects households' agricultural labor has long been a topic of debate. For instance, Chen et al. [34] argued that the development of e-commerce has promoted the growth of non-agricultural employment in rural areas, while Wang et al. [10] opined that e-commerce development has contributed to the migration of more people to rural areas.

The impact of agricultural labor migration within families on farmland abandonment also remains controversial. According to a study, for every 10% increase in non-agricultural employment, the average probability of farmland abandonment by farming households increases by 4% [5]. Yet, another group of scholars asserted that labor migration does not affect agricultural production; rather, it can effectively curb farmland abandonment through land transfer and intensive production [35]. Regardless of these contradictory results, existing research concurs in that farming households' e-commerce participation leads to changes in their agricultural labor, which is a direct cause of farmland abandonment.

Farming households' participation in e-commerce also promotes land transfer between different families [36], thereby reducing farmland abandonment. Owing to its powerful information dissemination capabilities, along with technological advancement, e-commerce has transformed land transfer from a mere institutional arrangement into an innovation. Land transfer among Chinese farming households is hampered by issues such as poor information flow and high transaction costs [37]. In response, e-commerce, based on internet platforms, has emerged as a powerful tool that breaks geographical barriers across trading parties, lowers information costs, and, thus, facilitates land transfers. Qin et al. [38] opined that the higher the level of e-commerce development, the greater the likelihood of land transfer among farming households. Several studies have confirmed that land transfer mitigates farmland abandonment [39], which implies that land resources are transferrable from low-productivity to high-productivity farming households, thereby achieving a Pareto improvement in land resource allocation [40], eventually mitigating farmland abandonment among farming households.

In summary, severe food security problems are prevalent not only in developed countries but also in developing countries, and e-commerce has been identified to play a pivotal role in ensuring the stability of agricultural product prices and supply capabilities. E-commerce has developed rapidly since its inception; global e-commerce sales reached \$5.2 trillion in 2021 and are expected to exceed \$8 trillion by 2026. Farmland abandonment poses a substantial threat to food security. Thus, exploring the co-occurrence of the e-commerce participation of farming households with farmland abandonment has emerged as a new direction of research. Given the multifaceted effect of farming households' e-commerce participation on farmland abandonment, this study performs a quantitative analysis based on a large-scale survey in China to better understand the co-occurrence of the e-commerce participation of farming households with farmland abandonment, providing crucial insights for addressing the global food security issue.

3. Data, Variables, and Method

3.1. Data

Data from the "China Rural Revitalization Survey" (CRRS), initiated by the Rural Development Institute of the Chinese Academy of Social Sciences, are used in this study and can be accessed at http://rdi.cass.cn/ggl/202210/t20221024_5551642.shtml, accessed on 8 January 2024. Unlike other databases, the CRRS database focuses on essential aspects such as "rural population and labor force", "rural industrial structure", "land use", and "comprehensive rural reforms", based on biennial follow-up surveys. The data used in this study were collected in 2020, surveying the situation in 2019. The survey covers 10 provinces (regions), namely, Guangdong, Zhejiang, Shandong, Anhui, Henan, Heilongjiang, Guizhou, Sichuan, Shaanxi, and the Ningxia Hui Autonomous Region, 50 counties (cities), 156 townships (towns), 300 villages, and over 3800 households. Comprehensively considering economic development levels, regional locations, and agricultural development, the database selects the samples randomly from provinces in the east, central, west, and northeast regions. To select the counties, it uses the equidistant random-sampling method based on the per capita GDP at the county level, aiming to cover the entire province (region) spatially. Townships (towns) and villages are randomly selected based on the local economic development level. Similarly, households are randomly selected from the rosters provided by village committees. Therefore, the selected sample is highly representative,

accurately reflecting the overall situation in China. Considering that the head of the household is the key decision-maker in the family [41], their responses are used as instrumental variables for family decisions. After processing, the data from 3831 farming households across 10 rural provinces in China were considered valid and analyzed in this study.

3.2. Variables

3.2.1. Dependent Variable

As this study investigates mainly the co-occurrence of the e-commerce participation of farming households with farmland abandonment, farmland abandonment by farming households is considered the dependent variable. As previously mentioned, this study measures farmland abandonment from the perspectives of explicit and implicit abandonment. For implicit abandonment decision, referring to the approach by Liu et al. [42] and others, this study defines samples where the income from cultivated land managed by households is ≤ 0 as cases of implicit abandonment and classifies the remaining cases as non-implicit abandonment. For the explicit abandonment rates, following the research of Zeng and Shi [43], this study defines explicit abandonment based on the abandonment rate. According to the questionnaire data, in this study, the explicit abandonment rate is calculated using Formula (1), thereby avoiding measurement errors potentially arising from direct inquiries to farmers about the existence and extent of the abandonment¹.

$$\text{Explicit Abandonment Rate} = (\text{Total Cultivated Land Area Managed by Farming Households} - \text{Actual Cultivated Area}) / \text{Total Cultivated Land Area Managed by Farming Households} \quad (1)$$

3.2.2. Core Explanatory Variable

This study considers farming households' e-commerce participation as the core explanatory variable. Wang et al. [10] conducted their research from a meso-level perspective, using e-commerce development aspects in villages (including whether e-commerce is widespread in the village, the e-commerce adoption rate, and the duration of e-commerce presence), to measure e-commerce development at the village level. Studying farming households from the micro-level perspective is crucial in exploring the mechanisms underlying farmland abandonment. Based on Qin et al. [38]'s approach, this study defines farming households' participation in e-commerce based on their involvement in online sales, which correspond to the following survey question: "Does the farming household sell products through online transactions"?

3.2.3. Control Variables

To rigorously control the impact of omitted variables, referring to previous studies [38,42,44], this study includes control variables at the levels of household heads, households, and villages, which are considered the factors affecting farmland abandonment by farming households. (1) At the household head level, this study controls variables such as the age, sex, and education level of the household head. (2) At the household level, factors such as the number of land plots managed by the family, family size, household income, the proportion of non-agricultural labor in the family, the number of elderly people engaged in agricultural labor, agricultural subsidies, cooperatives, and land transfers are controlled. (3) At the village level, variables like the proportion of labor force working outside the village, the per capita disposable income, the distance to the township government, topography, and location are controlled. Table 1 presents the model variables and summary statistics data.

Table 1. Descriptive analysis of the variables.

Variables	Definition and Assignment	Mean	Std. Dev.	Min	Max
E-commerce	Whether the farming household conducts product transactions online (0 = no; 1 = yes)	0.06	0.24	0	1
Explicit Abandonment Rate	(Total managed land area – actual planting area)/Total managed land area (%)	0.42	0.43	0	1
Implicit Abandonment Decision	Whether the planting income is less than or equal to zero (0 = no; 1 = yes)	0.40	0.49	0	1
Age	Age of the household head	55.01	11.24	21	91
Gender	Gender of the household head (0 = female; 1 = male)	0.93	0.25	0	1
Education Level	Education level of the household head (1 = primary or less; 2 = junior high; 3 = high school or above)	1.76	0.70	1	3
Number of Plots	Number of land plots contracted by the family (plots)	6.20	8.88	0	214
Family Size	Number of family members (persons)	4.15	1.52	1	10
Household Income	Logarithm of the total annual household income	10.67	1.18	2.30	16.12
Proportion of Non-agricultural Labor	Proportion of non-agricultural employment in the total household population (%)	0.24	0.26	0	1
Number of Elderly in Agricultural Labor	Number of members aged 60 and above who are engaged in agriculture in the family (persons)	0.42	0.81	0	6
Agricultural Subsidy	Whether the household receives agricultural subsidies (0 = no; 1 = yes)	0.87	0.33	0	1
Cooperative	Whether the household joined a cooperative (0 = no; 1 = yes)	0.24	0.43	0	1
Land Transfer	Whether there is transferred land in the family (0 = no; 1 = yes)	0.56	0.50	0	1
Proportion of Labor Force Working Outside	Proportion of labor force working outside in the total village labor force (%)	0.26	0.21	0	0.88
Per Capita Disposable Income	Logarithm of per capita disposable income	9.44	0.68	2.48	12.49
Distance	Logarithmic distance from the village committee to the township government	2.78	0.22	2.30	3.09
Topography	Topography of the farming household's location (1 = plain; 2 = hills; 3 = mountainous)	1.91	0.88	1	3
Location	Location of the farming household's area (1 = northeast; 2 = central; 3 = west; 4 = east)	2.91	0.93	1	4

3.3. Methods

3.3.1. E-Commerce Participation by Farming Households and Explicit Abandonment Rate: Tobit Model

The Tobit model has been selected primarily because the explicit fallow rate, a continuous variable between 0 and 1, exhibits left-censoring. Traditional linear models like OLS may bias estimates due to their inability to handle the variable's bounded nature and concentration. The Tobit model is suited for variables with limits, addressing left-censoring and providing accurate marginal effect estimates of independent variables on the dependent one. This is vital for evaluating the co-occurrence of the e-commerce participation of farming households with the explicit fallow rate, allowing for the precise measurement of changes across different e-commerce participation levels. Xie et al. [45] demonstrate the Tobit model's effectiveness in accurately assessing impacts. The model is specified as follows:

$$VA = \begin{cases} 0, & VA^* \leq 0 \\ VA^*, & VA^* > 0 \end{cases} \quad (2)$$

$$VA_i^* = \alpha + \beta E_commerce_i + \gamma X_i + \varepsilon_i \quad (3)$$

In Equations (2) and (3), VA represents the actual observed value of the implicit abandonment rate, and VA_i^* is the latent variable. Here, i denotes the surveyed farming house-

hold; $E_commerce_i$ indicates whether the farming household participates in e-commerce; X_i represents a series of control variables; α is the constant term; β and γ are the parameters to be estimated; and ε_i is the error term.

3.3.2. E-Commerce Participation by Farming Households and Implicit Abandonment Decision: Logit Model

Farming households' decision to implicitly abandon farmland is a binary discrete variable; statistically, it does not conform to the normal distribution and cannot be estimated using the ordinary least squares method. Factors affecting the decision of farming households to implicitly abandon land represent an unordered choice problem, that is, whether to choose implicit abandonment. An econometric model constructed using these decision outcomes as the dependent variable is known as a binary choice model. Referring to the research of Wang et al. [10], this study chooses the Logit model. Assuming that the random error term follows a logistic distribution, the Logit model is a binary discrete choice model, which is suitable for behavior decision models based on the principle of utility maximization [46]. The specific formula for the qualitative variable HA_i is as follows:

$$p(HA_i = 1|X_i, \beta_i) = \alpha + \beta E_commerce_i + \gamma X_i + \varepsilon_i \quad (4)$$

Here, HA_i represents whether the farming household has decided to implicitly abandon their farmland: its value is 1 in the case of implicit abandonment, and 0 otherwise. The definitions of the other variables are the same as in Equations (2) and (3).

4. Empirical Analysis Results

4.1. Descriptive Analysis of Farming Households' E-commerce Participation and Farmland Abandonment

4.1.1. E-Commerce Participation by Farming Households

As shown in Table 1, the mean value of the variable related to farming households' e-commerce participation is 0.06. This value is consistent with that observed for this variable by Luo [47], who also used the CRRS database, indicating that the value of the core explanatory variable calculated using the CRRS database in this study is accurate. Similarly, Luo et al. [48] analyzed data from two rounds of CRRS surveys in 2020 and 2021 and found the mean value of the variable related to e-commerce participation to be 0.04, which does not differ significantly from the value observed in this study. The results suggest that the overall level of e-commerce participation among Chinese farming households is low, concentrated in the range 4–6%. At the province level, the average e-commerce participation among farming households has been observed to be the highest in the Zhejiang province, whereas the average e-commerce participation values in Heilongjiang, Guizhou, and Ningxia are relatively low. These findings closely align with practical observations and are broadly consistent with the statistical results reported in the "2021 National County-Level Digital Agriculture and Rural E-commerce Development Report" published by the Ministry of Agriculture and Rural Affairs of China and the National E-commerce Center of China in 2021.

4.1.2. Implicit Abandonment Decision

The mean value of the variable related to the implicit abandonment decision among farming households is 0.40 (Table 1), implying that approximately 40% of the samples exhibit implicit abandonment. Given the scarcity of research on implicit abandonment, comparing this variable with explicit abandonment can be useful in the present context. In general, the explicit abandonment rate in China is nearly 20% [10,24]. Evidently, implicit abandonment is more severe in the country, indicating that measuring the co-occurrence of e-commerce participation with implicit abandonment holds a higher significance. Considering the decision to implicitly abandon farmland to be a binary variable, in this section, the average difference in the implicit abandonment decisions between the households participating and not participating in e-commerce is determined to preliminarily understand the sample structure and provide evidence for the choice of econometric models. Additionally,

the explicit abandonment rate and the main variables are tested, and the results are presented in Table 2. The descriptive statistics of the average difference in the characteristics between the farming households participating and not participating in e-commerce are provided in Table 2. Overall, the probability of implicit abandonment between farming households with and without e-commerce participation differs significantly, with those participating in e-commerce exhibiting a higher mean value of implicit abandonment. This pattern is consistent with that observed for the explicit abandonment rate, suggesting that e-commerce participation may be correlated positively with both the explicit abandonment rates and implicit abandonment decisions of farming households.

Table 2. Mean differences in the characteristics between farming households with and without e-commerce participation.

Variables	G1 (0)	Mean1	G2 (1)	Mean2	MeanDiff
Explicit Abandonment Rate	2750	0.408	183	0.619	−0.210 ***
Implicit Abandonment Decision	3490	0.405	234	0.470	−0.065 **
Age	3477	55.125	233	50.579	4.545 ***
Gender	3487	0.934	234	0.94	−0.006
Education Level	3490	1.744	234	2.038	−0.294 ***
Number of Plots	3109	6.179	199	7.377	−1.198 *
Family Size	3490	4.136	234	4.432	−0.296 ***
Household Income	3434	10.635	224	11.414	−0.779 ***
Proportion of Non-agricultural Labor	3471	0.239	232	0.27	−0.031 *
Proportion of Non-agricultural Labor	3488	0.428	234	0.312	0.116 **
Agricultural Subsidy	3490	0.878	234	0.859	0.019
Cooperative	3434	0.233	230	0.374	−0.141 ***
Cooperative	3479	0.554	233	0.588	−0.034
Proportion of Labor Force Working Outside	3430	0.261	232	0.244	0.017
Per Capita Disposable Income	3443	9.421	232	9.595	−0.174 ***
Distance	3440	2.784	231	2.784	0
Topography	3478	1.911	232	1.875	0.036
Region	3490	2.889	234	3.051	−0.162 ***

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

4.1.3. Explicit Abandonment Rate

Table 1 shows that the mean and standard deviation of the explicit abandonment rate are 0.42 and 0.43, respectively, indicating the possibility of an overestimation of the explicit abandonment rate if the mean value is used to predict the overall situation. Further observations suggest that the explicit abandonment rate is less than 0.32 for the top 50% of the samples, which may be closer to the overall situation. However, this figure is still higher than the explicit abandonment rate of approximately 20% reported in the literature. We believe that existing studies may have underestimated the situation of explicit abandonment in China as these studies obtained information about explicit abandonment and specific area through direct inquiries. Given China's strict policies against farmland abandonment and the use of land monitoring technology, this method may underestimate the extent and area of farmlands explicitly abandoned by Chinese farming households. The CRRS database uses inquiries to gather information about farmland, which might introduce some errors. However, compared with direct inquiries on abandoned farmland areas, this method can more accurately reflect the actual situation of farmland abandonment. Similarly, we have compared the mean values of explicit abandonment rates across different households, as shown in Figure 2. It can be preliminarily inferred that e-commerce participation increases the rate of explicit abandonment by farming households. Based on the above analysis, this study hypothesizes that e-commerce participation by farming households may increase the likelihood of implicit abandonment and the rate of explicit abandonment. Subsequently, we will test this relationship using econometric models.

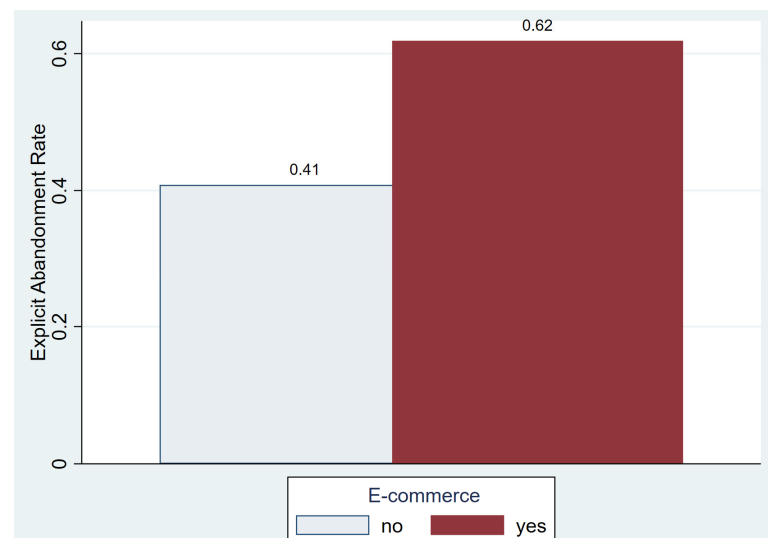


Figure 2. Comparison of the mean explicit abandonment rate of e-commerce farmers and non-e-commerce farmers.

4.2. Empirical Analysis Results

4.2.1. Baseline Results

Table 3 presents the baseline results of the co-occurrence of farming households' e-commerce participation with implicit abandonment decisions and explicit abandonment rates. The Logit regression results in Column (1) indicate that the marginal effect of e-commerce participation is 0.103 and statistically significant at the 5% level, indicating that e-commerce participation increases the probability of implicit farmland abandonment by farming households by 10.3%. The Tobit regression results in Column (3) indicate that the marginal effect of e-commerce participation is 0.285 and statistically significant at the 1% level, suggesting that e-commerce participation increases the explicit abandonment rate by 28.5%. To verify these results, robustness checks have been conducted using linear models, and the results of these linear simulations are consistent with those of the Logit and Tobit regression models.

Table 3. Benchmark results for the correlation between e-commerce participation by farming households and farmland abandonment.

Dependent Variable	Implicit Abandonment Decision		Explicit Abandonment Rate	
	(1) Logit	(2) LPM	(3) Tobit	(4) LPM
E-commerce Participation	0.103 ** (3.13)	0.106 ** (3.01)	0.285 *** (5.16)	0.188 *** (5.45)
Control Variables	Controlled	Controlled	Controlled	Controlled
Number of Observations	3085	3085	2719	2719
R ² /Pseudo R ²	0.117	0.130	0.030	0.055

Note: The values in parentheses are t-statistics. *** and ** indicate significance at the 1% and 5% levels, respectively. This table reports the marginal effect estimates of the model.

To confirm that the baseline regression results of this study are not affected by the random factors, following the approach of Tang et al. [49], we have conducted a permutation test as a placebo test. This approach involves randomly assigning the status of e-commerce participation by the sampled farming households, followed by 1000 Monte Carlo simulations, to obtain regression coefficients. These coefficients are then used to construct a statistic for verifying the probability that the coefficients obtained in the baseline regression are zero in the simulated distribution, that is, to obtain a *p* value. The permutation test results reject the null hypothesis that farming households' e-commerce participation has no significant association with both the probability of implicit abandonment and the explicit

abandonment rate at the 5% and 1% confidence levels, respectively², thus verifying that the baseline regression results of this study are not due to other random factors.

To ensure the reliability of the findings, additional robustness tests have been conducted, as follows: (1) a 2% level cut-off has been applied for continuous variables to mitigate the impact of outliers; (2) alternative econometric models, particularly the Probit model³ and the double-hurdle model, have been utilized for a nuanced estimation of both implicit abandonment decisions and explicit abandonment rates; (3) a revised binary variable for household e-commerce participation has been introduced based on the reported online sales revenue for 2019, which serves as a substitute for the initial key explanatory variable. The consistency of the results across these methods reinforces the validity of this study's conclusions⁴.

4.2.2. Addressing Endogeneity Issues

In empirical research, endogeneity issues primarily stem from reverse causation, measurement errors, and omitted variables. Given the rarity of the participation in e-commerce due to farmland abandonment, it is assumed that the problem of reverse causation does not exist in the relation between farming households' e-commerce participation and farmland abandonment. The survey questionnaire, being part of a comprehensive and systematic inquiry into rural revitalization, measures the core explanatory variable—whether farming households conduct online product transactions effectively—as described in previous research [38]. Moreover, the robustness of the findings has been tested by substituting explanatory variables, indicating that the impact of measurement errors should be within controllable limits. Therefore, to resolve potential endogeneity issues arising from omitted variables, this study primarily focuses on selecting suitable instrumental variables.

According to the theory of peer effects, peer behavior is an important determinant of individual behavior [50]. Consequently, most of the literature follows the theory of peer effects when selecting instrumental variables. For example, Ma et al. choose the decision of peers to engage in non-agricultural work as an instrumental variable, representing the family's decision regarding non-agricultural employment [51]. Therefore, based on the village questionnaire, this study selects “whether any households in the village operate an online store” as an instrumental variable representing farming households' e-commerce participation. Regarding the assumption of relevance, e-commerce development tends to have a cascading effect—the presence of households in the village operating online stores increases the likelihood of other households participating in e-commerce, satisfying the requirement for strong relevance, a fact substantiated by the subsequent empirical analysis. The Rational Peasant Theory posits that the operation of online stores by households in a village generally does not affect the land use decisions of other households in the village. Hence, the chosen instrumental variable is unlikely to directly affect the farming households' farmland abandonment decisions.

Table 4 presents the estimation results obtained using the instrumental variable method. Looking at the first stage, the instrumental variable shows a significant positive correlation with farming households' e-commerce participation in terms of both implicit abandonment decisions and explicit abandonment rates. Additionally, the first-stage Kleibergen-Paap F-statistic (KPF) values for the two variables are 23.818 and 23.929, respectively, which are higher than the critical value of 8.96 for rejecting the weak instrumental variable test at the 10% level. This suggests that no weak instrumental variable issues exist in this study. Furthermore, the Hausman test indicates that the explanatory variables are endogenous, indicating the suitability of the choice of the instrumental variable method.

Table 4. Correlation of e-commerce participation by farming households and farmland abandonment: instrumental variable method.

Dependent Variable	Second-Stage Regression Results			
	Implicit Abandonment Decision (1) IVProbit	(2) 2SLS	Explicit Abandonment Rate (3) IVTobit	(4) 2SLS
E-commerce Participation or Not	3.863 ** (2.77)	1.305 ** (2.82)	3.571 *** (3.92)	2.134 *** (4.02)
Control Variables	Controlled	Controlled	Controlled	Controlled
Number of Observations	2977	2977	2628	2628
Endogeneity Test χ^2	8.91	42.61	29.32	42.10
First-Stage Regression Results				
Instrumental Variable KPF		0.044 *** (5.05) 23.818		0.047 *** (5.05) 23.929

Note: The values in parentheses are t-statistics. *** and ** indicate significance at the 1% and 5% levels, respectively. This table reports the marginal effect estimates of the model.

After addressing the endogeneity issue, the second-stage results of the 2SLS (two-stage least squares) analysis consistently show a significant positive effect of e-commerce participation by farming households on both implicit decisions and the explicit abandonment rates. The marginal effects of e-commerce participation on the implicit abandonment decisions and the explicit abandonment rates determined using the instrumental variable method are found to be greater than those in the baseline results. This may be because the instrumental variable method mitigates the endogeneity issues arising from the omitted variables. Additionally, IVProbit and IVTobit estimations have been conducted, which yield similar results, verifying the robustness of the findings.

In addition to addressing endogeneity issues arising from omitted variables using the instrumental variable method, we have considered the potential co-occurrence of internet usage by farming households with farmland abandonment. Research suggests that the use of internet by farming households can help reduce explicit farmland abandonment [21]. Given that e-commerce participation by farming households occurs through the internet, does internet usage affect the result of this study? To confirm that the co-occurrence of e-commerce participation with farmland abandonment observed in this study is due to e-commerce activity rather than being the result of internet use, we have employed the survey question on “household internet devices” to introduce a variable indicating whether a household uses the internet. A value of 1 is considered to denote internet usage, whereas a value of 0 indicates no internet usage. This variable serves as a proxy for internet usage by farming households and has been included in the baseline regression analysis. As shown in Table 5, even after controlling for the variable related to internet usage, the co-occurrence of the e-commerce participation of farming households with both implicit abandonment decisions and explicit abandonment rates remains significant and positive, indicating that the findings of this study still hold true after taking into account the factor of internet use.

Table 5. Impact of internet use by farming households.

Dependent Variable	Implicit Abandonment Decision	Explicit Abandonment Rate
E-commerce Participation by Farming Households	0.103 ** (3.13)	0.284 *** (5.15)
Internet Usage by Farming Households	0.004 (0.12)	0.016 (0.28)
Control Variables	Controlled	Controlled
Number of Observations	3085	2719
Pseudo R ²	0.117	0.030

Note: The values in parentheses are t-statistics. *** and ** indicate significance at the 1% and 5% levels, respectively. This table reports the marginal effect estimates of the model.

4.2.3. Addressing Self-Selection Issues

In the context of e-commerce participation by farming households, the allocation is not entirely random, and some unobservable factors might lead to self-selection biases

in the sample. To eliminate the potential biases arising due to unobservable factors, this study has employed a treatment effects model, which might offer more accurate estimates, compared to the instrumental variable method, for binary variables such as e-commerce participation [52]. In the first stage of the treatment effects model, where a binary variable serves as the dependent variable, a Probit model is employed for estimation. In addition to the usual control variables, the Probit model requires exogenous exclusionary variables. Continuing with the theme of this research, “whether any households in the village operate an online store” is again used as an instrumental variable to represent farming households’ e-commerce participation. The regression results are presented in Table 6, reinforcing that the co-occurrence of the e-commerce participation of farming households with both implicit abandonment decisions and explicit farmland abandonment rates is significant and positive.

Table 6. Correlation of e-commerce participation by farming households and farmland abandonment: treatment effects model.

Dependent Variable	Implicit Abandonment Decision		Explicit Abandonment Rate	
	(1) 1st Stage	(2) 2nd Stage	(3) 1st Stage	(4) 2nd Stage
E-commerce Participation		0.536 ** (2.88)		0.923 *** (5.25)
Instrumental Variable	0.42 *** (4.95)		0.446 * (4.88)	
Control Variables	Controlled	Controlled	Controlled	Controlled
Number of Observations	2977	2977	2628	2628
Endogeneity Test (χ^2)		42.61		42.10

Note: The values in parentheses are t-statistics. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. This table reports the marginal effect estimates of the model.

In addition to the influence of unobservable factors, farming households’ participation in e-commerce may also be affected by certain observable characteristics. To address potential self-selection problems caused by observable variables, this study has employed propensity score matching (PSM). Initially, a Logit model is applied to estimate the probability of e-commerce participation by farming households and calculate their propensity scores. Subsequently, based on the propensity scores, a one-to-four matching is performed between the treatment and control groups, and the average differences between the two groups after matching are estimated. To ensure the reliability of the PSM results, a balance test is conducted, which, in the case of our study, indicates that the treatment and control groups exhibit no significant difference in terms of the characteristic variables ($p > 0.9$), and the standardized biases are mostly lower than 10%, indicating the effectiveness of the matching process and results. Table 7 shows that the results remain robust even after regression using the PSM method.

Table 7. Correlation of e-commerce participation by farming households and farmland abandonment: psm regression results.

Dependent Variable	Implicit Abandonment Decision	Explicit Abandonment Rate
E-commerce Participation	0.090 ** (2.32)	0.185 *** (5.28)
Control Variables	Controlled	Controlled
Number of Observations	3085	2719

Note: The values in parentheses are t-statistics. *** and ** indicate significance at the 1% and 5% levels, respectively. This table reports the marginal effect estimates of the model.

In addition to the primary assumptions of the baseline regression analysis in this study, the presumption that the e-commerce environment is uniform across all the villages where the surveyed farming households reside is worthy of consideration. However, this assumption does not entirely align with reality, and the presence and quality of the infrastructure required to support e-commerce activities can vary significantly across villages. This aspect

could influence the baseline regression results of this study. For instance, households in villages with better e-commerce infrastructure are more likely to engage in e-commerce activities, thus introducing potential sample selection bias in our primary findings. To address the potential self-selection issue, we restricted our sample selection, specifically including the villages with relatively advanced e-commerce infrastructure, to compare the co-occurrence of e-commerce participation with farmland abandonment in these areas. The selected villages have been categorized as having advanced e-commerce infrastructure based on the survey item “Does the village have an e-commerce service station or product consignment point?”, with a positive response indicating robust infrastructure. As depicted in Table 8, the co-occurrence of e-commerce participation by farming households with farmland abandonment remains significant and positive, even after considering this selection effect.

Table 8. Samples restricted to villages with better e-commerce infrastructure. I have added it.

Dependent Variable	Implicit Abandonment Decision	Explicit Abandonment Rate
E-commerce Participation	0.119 ** (2.61)	0.144 * (2.07)
Control Variables	Controlled	Controlled
Number of Observations	1481	1302
Pseudo R ²	0.097	0.032

Note: The values in parentheses are t-statistics. ** and * indicate significance at the 5% and 10% levels, respectively. This table reports the marginal effect estimates of the model.

4.3. Analysis of Mechanisms

To validate the theoretical framework constructed in this study, we have examined the mechanisms of planting income, agricultural labor, and land transfer.

4.3.1. Fundamental Cause: Income of Planting

Rural e-commerce development primarily aims to enhance the sale of agricultural products and increase farming households' income [13]. Therefore, in this section, first, the impact of e-commerce participation on household income is examined. Column (1) of Table 9 indicates that e-commerce participation significantly increases the households' income, consistent with the finding of another study [12]. The other findings can be summarized as follows: ① E-commerce participation does not significantly affect non-agricultural income, property income, or transfer income, contradicting the results of some previous studies. For example, Zhang Haixia and others opined that e-commerce in its initial development stage increases wage income by creating non-agricultural employment opportunities, thereby “crowding out” agricultural production activities [20]. This “contradictory conclusion”, to some extent, indicates that the comprehensive development of rural e-commerce has changed reality. E-commerce development has been attracting more labor to stay in rural areas and engage in agricultural production activities. ② E-commerce participation significantly increases the net income from forestry, animal husbandry, and fisheries but significantly decreases the net income from planting. A decrease in planting income has been shown to result in farmland abandonment. This can compel farming households to invest less in farmland, thus increasing the likelihood of abandonment. This also accounts for the discrepancies in the conclusions of this study and those of other studies, including Wang [10]'s study.

Table 9. E-commerce participation by farming households, planting income, and farmland abandonment.

Dependent Variable	(1) Household Income	(2) Net Planting Income	(3) Net Income from Forestry, Animal Husbandry, and Fisheries	(4) Non-agricultural Income (Including Business and Wage Income)	(5) Property Income	(6) Transfer Income
E-commerce Participation	0.554 *** (6.94)	−0.538 * (−2.24)	1.616 *** (5.48)	−0.339 (−1.26)	−2.590 (−1.26)	0.106 (0.66)
Control Variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant Term	8.567 *** (20.69)	5.417 *** (4.06)	−2.470 (−1.44)	−9.639 (−6.06)	−4.681 *** (−4.00)	−0.323 *** (−7.50)
Number of Observations	3085	2905	2482	2508	2532	2767
Pseudo R ²	0.072	0.203	0.137	0.313	0.219	0.154

Note: The values in parentheses are t-statistics. *** and * indicate significance at the 1% and 10% levels, respectively. This table reports the marginal effect estimates of the model.

4.3.2. Direct Cause: Insufficiency of Planting Labor

The results of the analysis presented in Table 9 indicate that the participation in e-commerce significantly increases farming households' income from forestry, animal husbandry, and fisheries, while simultaneously decreasing the income from planting. This trend suggests that the additional labor in farming households is more likely being channeled into forestry, animal husbandry, and fisheries rather than crop cultivation. Due to limited data availability, discussing the specific directions of labor shifts within these households is challenging. However, based on this logic, we posit that e-commerce participation might reduce the proportion of non-agricultural labor in these households. Therefore, we have examined the correlation between e-commerce participation and the proportion of non-agricultural labor in the surveyed households. The results are presented in Table 10, indicating that e-commerce participation significantly reduces the proportion of non-agricultural labor in the households. This finding indicates that e-commerce participation diminishes the shift of labor in agricultural households to non-agricultural sectors. However, the labor force that is not moving toward non-agricultural activities is being channeled into forestry, animal husbandry, and fisheries rather than planting, leading to a lack of labor for planting, eventually exacerbating the issue of farmland abandonment.

Table 10. E-commerce participation by farming households, labor mobility within families, and farmland abandonment.

Dependent Variable	(2) Proportion of Non-Agricultural Labor in the Household
E-commerce Participation	−0.038 * (−2.13)
Control Variables	Controlled
Constant Term	0.546 *** (5365)
Number of Observations	3085
Pseudo R ²	0.098

Note: The values in parentheses are t-statistics. *** and * indicate significance at the 1% and 10% levels, respectively. This table reports the marginal effect estimates of the model.

A general consensus is that rapid industrialization and urban development have led a substantial portion of agricultural labor to transition from less productive agricultural sectors to non-agricultural sectors [53]. However, our findings diverge from this consensus, which may be attributed to the policies aimed at promoting rural revitalization in China, like e-commerce, which have been attracting more labor to return to rural areas. In addition, our conclusion aligns with those of Wang et al. [10] and others, who reported that e-commerce

has accelerated the return of labor to rural areas. These trends indicate a dynamic shift in the labor patterns, contrasting the traditional pattern of shifts from rural to urban settings, supporting that developments in rural policy and technology reverse the flow of labor.

4.3.3. Mitigating Factor: Land Transfer

As previously discussed, e-commerce participation by farming households significantly increases both explicit and implicit farmland abandonment. So, does land transfer alleviate the co-occurrence of e-commerce participation with farmland abandonment? As shown in Table 11, in terms of the explicit abandonment rate, the interaction term between e-commerce participation and land transfer is nonsignificant. However, the co-occurrence of e-commerce participation with the explicit abandonment rate remains significant, and its marginal effect is greater than that observed in the baseline regression results. This indicates that, even after controlling for the interaction between e-commerce participation and land transfer, the co-occurrence of e-commerce participation with the explicit abandonment rate remains positive. For implicit abandonment decisions, the interaction term is found to be significant. E-commerce participation is significantly associated with the incidence of implicit farmland abandonment decisions, consistent with the baseline regression results. This suggests that, compared with the households not engaged in land transfer, those engaged in land transfer exhibit a lower likelihood of implicit abandonment due to e-commerce participation. In other words, land transfer can effectively mitigate the probability of implicit abandonment induced by e-commerce participation. However, despite the role of land transfer in mitigating the association between e-commerce participation and implicit abandonment, the reality is that, due to the significant social security function which land still holds in China, most land-contracting families are not keen on transferring their land. Thus, active land transfer by farming households is rare. Land transfer organized at the village collective level provides distinct advantages in terms of operational scale and structural adjustment of cultivation [54], which implies that village collectives are more likely to achieve large-scale land transfers than individual households. This also explains the reasons for the finding of Wang et al. [10], who propounded that the proliferation of rural e-commerce can significantly inhibit farmland abandonment, contradicting that of our study, which suggests that e-commerce participation by farming households exacerbates farmland abandonment.

Table 11. E-commerce participation by farming households, land transfer, and farmland abandonment.

Dependent Variable	Land Transfer	
	(1) Explicit Abandonment Rate	(2) Implicit Abandonment Decision
E-commerce Participation	0.324 *** (1.02)	0.953 *** (3.89)
E-commerce Participation * Dummy Variable for Land Transfer Group	−0.072 (−0.66)	−0.805 * (−2.39)
Dummy Variable for Land Transfer Group	Controlled	Controlled
Other Variables	Controlled	Controlled
Constant Term	−0.458 (−1.45)	−1.713 (−1.78)
Sample Size	2719	3085
R-squared	0.030	0.119

Note: The values in parentheses are t-statistics. *** and * indicate significance at the 1% and 10% levels, respectively. This table reports the marginal effect estimates of the model.

Figure 3 depicts the relationship and patterns observed between farming households' e-commerce participation and farmland abandonment. Participation in e-commerce boosts households' income, specifically that from forestry, animal husbandry, and fisheries, while notably suppressing planting income. Acting rationally, households reduce their investment in non-agricultural labor, redirecting their shift to the more lucrative forestry, animal husbandry, and fishery sectors. Under the fixed household labor resource constraints,

households are compelled to reduce labor input in planting, leading some families to abandon their farmland (explicit abandonment) and other households to choose to maintain cultivation to reduce the effective labor input, thereby increasing the likelihood of implicit abandonment. In this context, actively promoting land transfer can help reduce the incidence of the implicit abandonment associated with farming households' participation in e-commerce. This dynamic underscores how shifts in labor allocation within rural households, influenced by the opportunities and income potential of e-commerce, can affect agricultural land use and management.

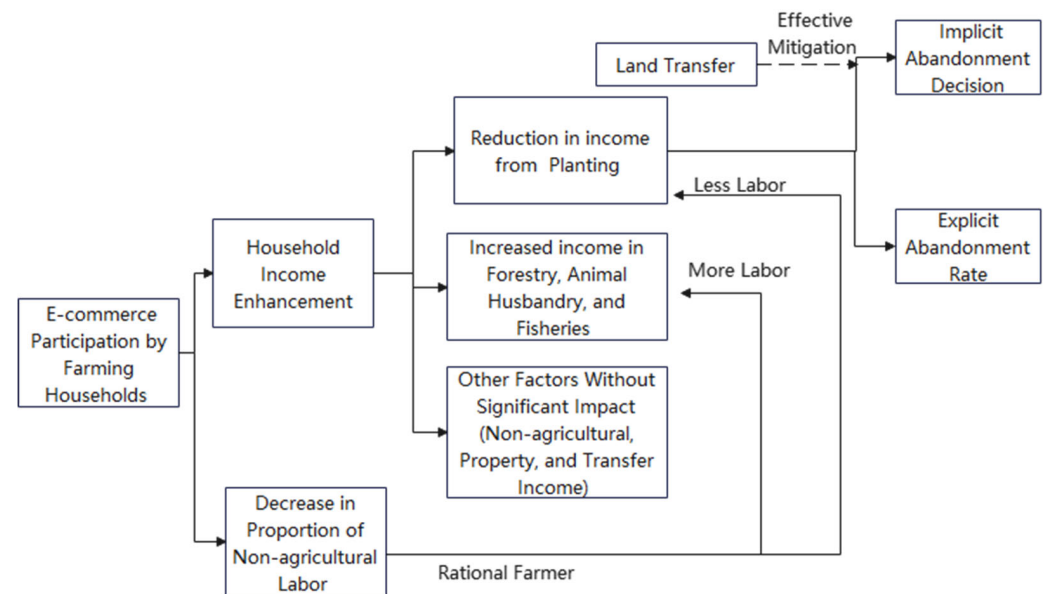


Figure 3. Relationship and patterns between e-commerce participation by farming households and farmland abandonment.

4.4. Heterogeneity Analysis

Land policy, economic development, and large-scale operation are the major factors affecting farmland abandonment. Therefore, we examined the heterogeneity in the co-occurrence of the e-commerce participation of farming households with farmland abandonment from three dimensions, namely, agricultural subsidies (land policy), per capita income (economic development), and family farms (large-scale operation). The results are presented in Tables 12 and 13.

Table 12. Results of the heterogeneity analysis of explicit abandonment rates.

Dependent Variable	Explicit Abandonment Rate					
	Agricultural Subsidy		Per Capita Income		Family Farm	
	(1) Received	(2) Not Received	(3) Low	(4) High	(5) Registered	(6) Not Registered
E-commerce Participation	0.287 *** (4.85)	0.197 (1.30)	0.183 * (2.56)	0.311 *** (4.01)	0.043 (0.30)	0.305 *** (5.11)
Control Variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant Term	−0.658 * (−2.00)	0.653 (0.68)	1.515 *** (3.81)	1.731 (2.45)	−1.871 (−1.40)	−0.313 (−0.96)
Sample Size	2496	223	2056	663	108	2583

Note: The values in parentheses are t-statistics. *** and * indicate significance at the 1% and 10% levels, respectively. This table reports the marginal effect estimates of the model.

Table 13. Results of the heterogeneity analysis of implicit abandonment decisions.

Dependent Variable	Implicit Abandonment Decision					
	Agricultural Subsidy		Per Capita Income		Family Farm	
	(1) Received	(2) Not Received	(3) Low	(4) High	(5) Registered	(6) Not Registered
E-commerce Participation	0.115 ** (3.33)	−0.023 (−0.24)	0.137 ** (3.34)	0.060 (1.09)	−0.125 (−1.16)	0.134 *** (3.81)
Control Variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Constant Term	−2.799 ** (−2.73)	0.284 (0.10)	−0.330 (−0.26)	−0.649 (−0.28)	−0.182 (−0.03)	−1.998 * (−2.03)
Sample Size	2761	324	2256	829	110	2939

Note: The values in parentheses are t-statistics. ***, ** and * indicate significance at the 1%, 5% and 10% levels, respectively. This table reports the marginal effect estimates of the model.

4.4.1. Agricultural Subsidies

Farming households receiving agricultural subsidies and participating in e-commerce tend to significantly increase farmland abandonment, whereas those not receiving subsidies do not show any significant change in their abandonment decisions (Table 12). A possible explanation is that, although the Chinese government initiated a pilot reform of “three agricultural subsidies” in 2015, shifting the basis for agricultural subsidy distribution from land-contracting rights to land-operating rights to prioritize support for the households cultivating more land, the separation of land-contracting rights from operating rights due to the large-scale migration of rural labor to cities has resulted in the distribution of subsidies based on the operating rights between the parties involved in land transfer [55]. Considering the high population density and limited land availability, the land contractor holds the right to speak during the distribution process [54], implying that agricultural subsidies are more likely to end up with land contractors. This can, to some extent, increase the operating costs for land operators, potentially exacerbating farmland abandonment.

4.4.2. Per Capita Income

The sample has been divided into groups with high and low per capita incomes, considering the average per capita income within villages in 2019 as the standard. As shown in Table 12, regardless of the per capita income, farming households’ participation in e-commerce significantly increases the explicit farmland abandonment rate. This can be explained as follows: e-commerce reduces the transaction costs and barriers, allowing farmers to earn from forestry, animal husbandry, and fisheries, irrespective of their income. The increased income level of farmers, in turn, reduces the labor input in planting, exacerbating the rate of explicit abandonment. Conversely, e-commerce participation significantly increases the likelihood of implicit abandonment only in areas with a lower per capita income. This aligns with previous research results, suggesting that less-developed areas, often remote, face challenges such as limited labor and aging infrastructure [22]. These challenges can lead to insufficient investments in the farmland, increasing the probability of both explicit and implicit abandonment.

4.4.3. Being Registered as a Family Farm

As shown in Table 12, farming households not registered as family farms and participating in e-commerce significantly increase farmland abandonment. In contrast, for those registered as family farms, the co-occurrence of the e-commerce participation of farming households with farmland abandonment decisions is not significant. This can be explained as follows: family farms relying on family members for labor face a shift from “implicit” opportunity costs to “explicit” rental expenses when they take over land from other farmers. This explicit cost of land can incentivize family farms to invest more in their farmland [56]. However, smallholders who do not derive their income solely from planting exhibit a low motivation to invest heavily in farmland, which increases the likelihood of abandonment.

5. Discussion

5.1. Conclusions and Discussion

Based on survey data from 3831 rural households across 10 provinces in China and guided by the Rational Peasant Theory, this study constructs the following theoretical framework: “E-commerce Participation by Farming Households–Family–Farmland Abandonment”. This study also empirically explores the association between e-commerce participation and farmland abandonment, including the underlying patterns. The main conclusions are as follows:

(1) Farming households’ participation in e-commerce significantly exacerbates farmland abandonment. Specifically, it increases the probability of implicit abandonment by 10.3% and the rate of explicit abandonment by 28.5%. Currently, there are no studies directly discussing the relationship between e-commerce participation at the household level and farmland abandonment. Wang et al. suggest that the widespread adoption of e-commerce at the village level can significantly inhibit farmland abandonment [10], which appears to be contrary to our research findings. A possible explanation we offer is that, at the village level, mechanisms such as land transfer can mitigate the overall farmland abandonment rate, a solution which is more challenging to implement at the household level.

(2) Regarding nature and patterns, participation in e-commerce significantly boosts the income from forestry, animal husbandry, and fishery sectors but notably suppresses the planting income. Additionally, it significantly reduces the proportion of non-agricultural labor. Acting rationally, households shift this non-agricultural labor to more lucrative sectors such as forestry, animal husbandry, and fisheries. Under fixed household labor constraints, this shift naturally causes a reduction in labor for planting, forcing some households to abandon farming (explicit abandonment) and others, who wish to maintain cultivation, to reduce their effective labor input, thereby increasing farmland abandonment (implicit abandonment). Land transfer can help mitigate the association between e-commerce participation by households and the occurrence of implicit abandonment. This result aligns with existing research indicating that the development of rural e-commerce has increased farmers’ income [11,30], but our study further finds that this income growth does not stem from planting but rather from forestry, animal husbandry, and fisheries. Additionally, our findings, consistent with Wang et al. [10]’s, show that rural e-commerce development attracts more labor to return to rural areas. In this process, land transfer can mitigate the implicit land abandonment associated with households’ participation in e-commerce, which is generally in agreement with existing studies suggesting that land transfer helps to alleviate farmland abandonment [25].

(3) From the perspective of heterogeneous effects, agricultural subsidy policies have exacerbated the increase in farmland abandonment associated with farmers’ participation in e-commerce, consistent with Wang et al.’s findings [25]. The reason might be that agricultural subsidies are more likely to be obtained by land contractors, thereby increasing operational costs and leading to land abandonment. Family farms effectively mitigate this effect, reinforcing Jin et al.’s research, which highlighted the role of family farms in alleviating land abandonment [56]. There is no heterogeneity in the co-occurrence between e-commerce participation of farming households and explicit abandonment with higher per capita incomes, whereas, in regions with lower per capita incomes, e-commerce participation significantly increases implicit abandonment. This lack of heterogeneity might be related to the weak infrastructure in economically underdeveloped areas [22].

5.2. Policy Recommendations

In developing countries, the development of e-commerce provides a novel approach to addressing the global food security concern from the perspective of farmland abandonment. However, our research suggests the need to exercise caution in developing e-commerce in rural areas. We noted that participation in e-commerce exacerbates both implicit and explicit farmland abandonment at the household level. Based on the findings of the above study, to better understand the association between increased farmland abandonment and farmers’

participation in e-commerce while also considering the economic development levels and specific conditions of different regions, this paper proposes the following countermeasures and recommendations:

(1) The participation of farmers in e-commerce may exacerbate the issue of farmland abandonment, a situation more likely to occur in regions with uneven resource distribution and areas with rapid non-agricultural labor transfer. To address these areas, more targeted policy interventions are necessary, such as devising policies to enhance the income of farmers not involved in e-commerce, in order to reduce the incidence of farmland abandonment. Additionally, there is a need to particularly strengthen the construction of agricultural production infrastructure in economically underdeveloped areas to prevent local shortages in planting labor caused by e-commerce development.

(2) Develop policies tailored to different regions. For areas with a lower per capita income, it is recommended to formulate policies that support farmers' participation in e-commerce while also enhancing the attractiveness and sustainability of agriculture. For example, providing agricultural technology training, increasing agricultural subsidies, and optimizing the land transfer mechanism are a few of these strategies. For areas with a higher per capita income, considering that participation in e-commerce is minimally associated with explicit farmland abandonment, policies can focus more on improving agricultural production efficiency and promoting the upward channel of agricultural products.

(3) Actively promote the construction of family farms. By highlighting the positive role of family farms in curbing farmland abandonment, in this paper, it is suggested to popularize the family farm model. By providing entrepreneurship guidance, loan support, and facilitating market access, more farmers are encouraged to adopt family farm operations, thereby enhancing the specialization and scale of agricultural production.

(4) Continuously improve the land transfer system. By simplifying the transfer procedures, increasing the transparency and security of land transfers, one would encourage farmers to transfer idle farmland to willing and capable farmers or enterprises, thereby reducing the rate of farmland abandonment.

It should be noted that the conclusions of this study are based on the specific geographical and socio-economic environment of China. These conclusions and their policy recommendations provide valuable insights for other regions, but, when extending them to other areas, it is necessary to consider the differences in the economic development levels, the agricultural structures, the prevalence of e-commerce, and the policy environments. Different regions need to take these differences into account when formulating policies, especially in cross-national comparisons and policy learning, requiring a careful assessment of the specific circumstances of each area.

5.3. Limitations and Future Prospects

This study has certain limitations that future research could further explore. Specifically, (1) this study mainly discusses the co-occurrence of the e-commerce participation of farming households with farmland abandonment from the perspective of farmers, but factors such as farmers and villages are all contributors to farmland abandonment. Future research could further discuss the impact of e-commerce participation on farmland abandonment under the joint effects of farmers and villages. (2) This study is primarily based on rational assumptions, but it must be acknowledged that farmers' decision making could be a complex result of both rational and irrational influences. For example, the low rate of land transfer among Chinese farmers is significantly influenced by their special emotional attachment to the land. Future studies could further explore cultural, emotional, and political factors to develop a more comprehensive understanding of farmers' land use decisions. (3) Due to the constraints of data availability, this study relies on cross-sectional data to examine the co-occurrence of e-commerce participation by farming households with farmland abandonment. While we have endeavored to address various potential endogeneity concerns through the strategic use of control variables and instrumental variables, it is important to acknowledge the inherent limitations of cross-sectional data in capturing dynamic relationship changes. Additionally,

it must be noted that, although our findings might suggest a potential causal relationship, the available data do not suffice to conclusively prove such a relationship. To overcome these limitations and gain a deeper understanding of the dynamics at play, future research should consider employing panel data, which would allow for a more thorough exploration of these dynamics. Furthermore, conducting field surveys and gathering firsthand data could offer a more precise insight into the causal relationship and the dynamic changes between farmers' participation in e-commerce and farmland abandonment. This approach would not only enhance the robustness of the findings but also contribute significantly to the academic discourse on the subject.

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Data Availability Statement: The data that support the findings of this study are available from the China Rural Revitalization Survey, but restrictions apply to the availability of these data, which were used under license for the current study and, as such, are not publicly available. These data are, however, available from the authors upon reasonable request and with permission from the China Rural Revitalization Survey.

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Notes

- ¹ Note: According to the design of the questionnaire, the total cultivated land area managed by farming households = the area of contracted land + the area of land transferred in + the area of open land – the area of land transferred out, and all of them are the data of the farm household in 2019.
- ² Due to space constraints, the test results are not shown. The authors can be contacted if needed.
- ³ This study also utilizes a logistic model to regress implicit abandonment decisions, and the conclusions remain robust.
- ⁴ Due to space constraints, the test results are not shown. The authors can be contacted if needed.

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