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The Impact of Farmers' E-Commerce Adoption on Land Transfer: Evidence from Ten Provinces across China

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Abstract: Rural e-commerce is rapidly expanding in rural China, profoundly affecting the agricultural and rural development of China. This paper focuses on the impact of farmers' e-commerce adoption on land transfer, aiming to reveal the role of farmers' e-commerce adoption in promoting rural transformation. Based on the 2020 Comprehensive Survey of Rural Revitalization in China conducted by the Chinese Academy of Social Sciences, this study employs the method of least squares and propensity score matching to evaluate the impact of farmers' e-commerce adoption on land-transfer behaviors in China. The results indicate that farmers' e-commerce adoption promotes farmers' participation in land transfer, significantly facilitating farmers' land transfer in and increasing the area of land acquired. Additionally, farmers' e-commerce adoption also promotes the trend of standardization and contractualization in land transfer, significantly increasing the probability of farmers signing formal agreements, clarifying lease terms, and renting land to strangers when acquiring land. This study can provide some theoretical inputs for policies to promote the development of agricultural land markets in developing countries and for policy formulation to promote e-commerce development.

Keywords: farmers' e-commerce adoption; land transfer; rural development; agricultural innovation; China



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1. Introduction

Developing countries generally face the problem of agricultural land fragmentation, which significantly constrains the transformation and development of agriculture and limits the rise of farmers' incomes [1,2]. Exploring effective ways to promote the transfer of agricultural land to achieve large-scale operations has become a topic of widespread concern in the academic community. Developing countries in South Asia, Africa, and other regions have adopted land reform policies to improve the situation of land fragmentation, and scholars are also actively researching the problem of land fragmentation and countermeasures to promote land transfers [3–5]. China, as the largest developing country in terms of economic size, faces even more prominent problems of rural land fragmentation and small-scale and scattered operations. The average per capita arable land area is less than 1 hectare [6]. Previous studies have shown that in 2003, the average land operation scale per rural household in China was 7.5 mu, with an average of 5.7 plots per household. By 2018, the per capita arable land area per household in the country was less than 7.5 mu, with a slight decrease in the average number of plots per household, but still around 5.5 plots [7]. The decentralized and small-scale land management model is no longer able to fully meet the needs of the large market and modernization. Also, land fragmentation will lead to the waste of arable land resources, increase agricultural production costs, and indirectly inhibit the increase in farmers' income [8,9].

Land transfer is one of the important means to solve land fragmentation and promote the centralized and contiguous operation of land [10] as well as to optimize land resource allocation and improve agricultural productivity. In recent years, the government has

attached great importance to the transfer of rural land contract management rights, issuing a series of documents, laws, and regulations to encourage farmers to carry out land transfers that are compatible with the current level of scientific and technological production. The government has also clearly regulated the ways and means of land transfer [11]. At the same time, rural society in China is characterized by a focus on kinship and personal relationships, and most of the land is traded among acquaintances, with a low proportion of paid and written contractualized transfers [12]. Scholars believe that land transfer among acquaintances is a kind of land transfer with low marketization and standardization [13,14]. Non-market land transfer hinders land integration, hinders the development of agricultural transfer markets, and is more likely to cause transaction disputes between farmers, limiting the increase in farmers' income [15,16]. Therefore, promoting land transfer and integration and facilitating the transition of land transactions to marketization and standardization is one of the means to promote the development of rural construction towards modernization.

Meanwhile, rural e-commerce is developing rapidly. According to the China Rural Digital Development Report, by 2022, online retail sales in rural China reached 2.17 trillion yuan. Studies have confirmed that adopting e-commerce can have a significant impact on the welfare of rural households. Some scholars believe that the entry of e-commerce into rural areas can effectively increase farmers' income. For instance, Qiu and Zhou [17] analyzed the positive impact of e-commerce development on rural residents' income from the perspective of effective demand and supply docking. Zeng et al. [18] found that participating in rural e-commerce can promote farmers' income growth by increasing profit margins and sales volume. Some scholars believe that adopting farmer e-commerce can narrow the urban–rural income gap by promoting farmers' income growth [17,19]. Existing research confirms that rural households participating in rural e-commerce improve their income structure, raise their living standards, and increase their risk awareness. The adoption of rural e-commerce by farmers improves the information asymmetry in traditional agricultural markets and enables farmers to obtain more information about product markets and sales channels [18,20,21]. This is conducive to reducing transaction costs and increasing farmers' production and operation income. With the increase in farmers' income, budget constraints are alleviated, making it more likely for them to transfer in land. Higher incomes for farmers have eased budgetary constraints, making it more likely that they will switch land. At the same time, due to the evaluation mechanism of the e-commerce platform, the adoption of e-commerce makes farmers have higher requirements for the quality and reputation of their products, and they are likely to ensure the quality of their products by renting land and operating their own business [22].

In addition, the adoption of e-commerce by rural households deepens the embedding of internal market mechanisms in rural areas, and the contractualization and standardization of land transfer will continue to improve. Existing studies have mostly explored the drivers of land transfer from other perspectives. Few studies have examined the impact of e-commerce adoption by farmers on land transfers [23]. Even if it does, it only mentions that e-commerce adoption affects land transfers, without specifically analyzing how it affects land transfers [24]. Based on this, this paper argues that e-commerce adoption by farmers is an important driving force to promote land transfer as well as contractualization and standardization of the transfer market. This paper will use nationally representative China Rural Revitalisation Survey (CRRS) data covering ten provinces to empirically reveal the impact of e-commerce adoption by farmers on their land-transfer participation and land-transfer marketization behaviors. Then it can provide feasible theoretical references to optimize the allocation of agricultural land resources and promote the transformation of the countryside into a modernized countryside. This study also provides a reference for other developing countries to cope with the problem of land fragmentation and promote land transfer, which helps other countries to optimize the allocation of resources, promote the transformation and upgrading of the rural economy, and improve the income of farmers, thus accelerating the modernization and development process of other developing countries. It also provides new research perspectives on the development of e-commerce

in these countries, which helps them formulate policies for e-commerce development and helps other countries better plan and manage their own rural e-commerce development.

The main contributions of this research include the following: First, it enriches the relevant literature on the socioeconomic impact of rural household e-commerce adoption, providing theoretical support for predicting the development of China's rural land market under the new era background. Existing research has mainly focused on studying the impact of rural e-commerce adoption on farmers' income [25–27], the urban–rural income gap [28], farmers' happiness [29], farmers' quality of life [12], and other welfare aspects, with relatively few studies on the impact of rural household e-commerce adoption on land transfer. Second, this study focuses on e-commerce, which has a widespread impact in rural China, enriching the literature on the driving factors of land transfer and providing a new perspective for research on land-transfer issues in other developing countries. Last, unlike the existing literature that mainly studies the impact of rural e-commerce on farmers at the village level, this study focuses on individual households, enriching the research on the welfare performance of rural e-commerce adoption at the household level.

The rest of this paper is organized as follows. Section 2 presents the theoretical analysis and research hypothesis. Section 3 introduces the materials and methods used in this study, and describes the variables. Section 4 presents the analysis results. Section 5 provides a discussion.

2. Theoretical Analysis and Research Hypotheses

Information is an important factor influencing the effective and rational allocation of resources in a market economy. In traditional markets, there is often asymmetric information, where one party possesses more and higher-quality information while the other party has less. In agricultural markets, farmers are often at a disadvantage in terms of information, receiving delayed and distorted market information [18]. However, the development of e-commerce has enhanced the information exchange between farmers and consumers, reducing information asymmetry. With the adoption of e-commerce, farmers can access market information timely and comprehensively, understand the market demand for agricultural products as well as consumer evaluations and needs, and adjust product supply accordingly. This reduces information search costs, improving their disadvantaged position [30,31]. Furthermore, e-commerce platforms can eliminate intermediary links, allowing farmers to set higher prices for their products [32]. With the dual mechanism of cost reduction and price increase, farmer incomes have significantly increased compared to before, allowing for more budget allocation to go toward land (Figure 1).

With the adoption of e-commerce, not only can farmers have a deeper and more timely understanding of the needs of the agricultural market, but consumers can also more accurately find agricultural products that meet their needs for purchase through the e-commerce channel. Then the goods provided by farmers and the goods needed by consumers can be more effectively matched, which helps to realize the matching of supply and demand, and thus increases the demand for agricultural products [33]. As the rational peasant, driven by profit, rural households will further expand the supply of their products through multiple channels, of which, in the context of easing budget constraints, scaling up operations through land transfers is a viable option [34]. Farmers may also expand the supply of their products by acting as middlemen, and there are also farmers who may choose to invest capital inputs in their existing land rather than expanding to increase outputs. However, it can be inferred that none of these farmers will choose to rent out their existing land. And so, on balance, the adoption of e-commerce by farmers will encourage them to rent land.

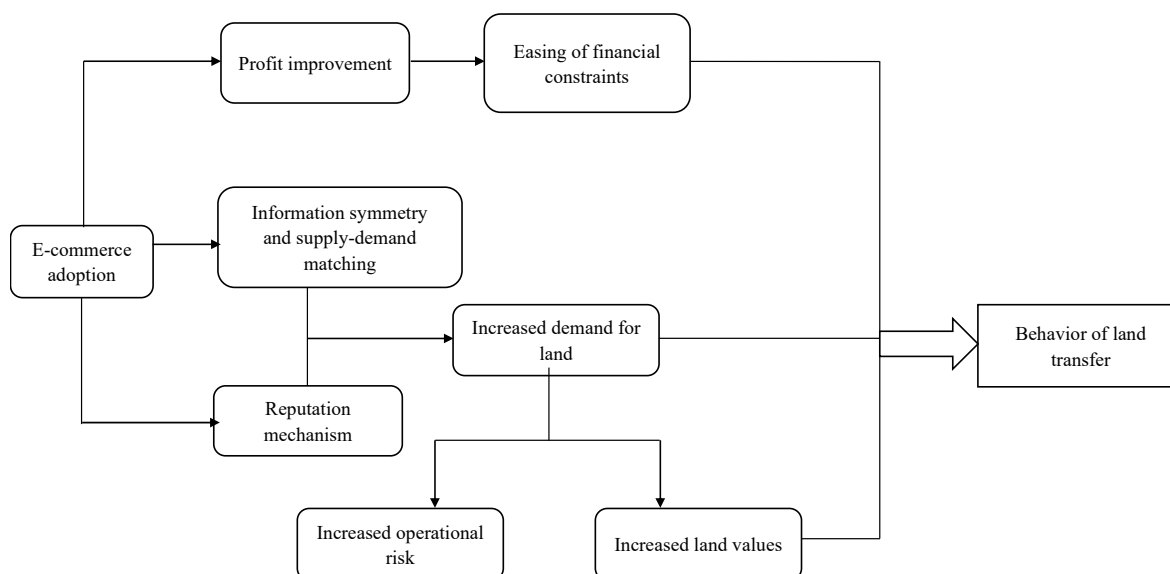


Figure 1. Logical framework diagram.

At the same time, e-commerce has a product display mechanism and a reputation incentive mechanism, and the orders can directly display previous consumers' evaluations of the products so that consumers can understand the quality of the products before purchasing [35,36]. This mechanism directly influences whether new customers will make purchases and whether old customers will repurchase, reinforcing the impact of agricultural product quality on consumer decisions [37]. Therefore, as rational peasants, farmers will value reputation evaluations, quality control, and product quality. To reduce the risk of product quality issues, compared to purchasing products of unknown quality from others, farmers will tend to internalize the risk by leasing more land for their own cultivation and, therefore, will promote the transfer of agricultural land. Based on this, the following research hypothesis is proposed:

Hypothesis 1. *The adoption of e-commerce will promote the transfer of agricultural land through profit enhancement, supply–demand matching, and reputation mechanisms.*

Further, e-commerce sales have made traditional agricultural production more closely linked to the market, and as farmers expand their production, they need to be more sensitive to market information and respond to changes in the market. Otherwise, they may face a backlog of products or even losses. This means that compared to farmers who have not adopted e-commerce sales, farmers who adopt e-commerce sales face relatively higher risks in production and operation. In addition, the participation of farmers in e-commerce represents the development of local e-commerce, increasing consumer demand for local agricultural products and prompting an increase in the transfer price of agricultural land rights [24]. This enhances the value represented by the land itself, further emphasizing the importance of land value to land transferees. With the adoption of e-commerce, land transactions become more active. The inevitable increase in transaction volume will inevitably bring more disputes [38]. From both the perspective of rising land value and the perspective of risk, farmers are more cautious when transferring land, preferring standardized and contractual means to ensure their rights. Therefore, to some extent, the adoption of e-commerce prompts farmers' land-transfer behavior to become more market-oriented, preferring a contractual mode dominated by the market rules of the stranger society.

Hypothesis 2. *The adoption of e-commerce will promote farmers to transfer land through more market-oriented and contractual means.*

3. Materials and Methods

3.1. Data Sources

This study utilizes data from the “China Rural Revitalization Survey” (CRRS), conducted by the Rural Development Institute of the Chinese Academy of Social Sciences from August to September 2020. The sample for this survey was drawn in accordance with the principle of multi-stage stratified random sampling. Considering the economic development and agricultural production of each province, provinces were randomly selected at a ratio of one-third in each of the eastern, central, western, and northeastern regions, and a total of ten provinces were selected. Counties were randomly sampled based on per capita GDP, with efforts made to cover the entire province spatially. Using the same sampling method, townships and villages were randomly selected based on their local economic development levels. Finally, sample households were randomly selected based on rosters provided by village committees. The selected provinces were Guangdong, Zhejiang, Shandong, Anhui, Henan, Heilongjiang, Guizhou, Sichuan, Shaanxi, and Ningxia Hui Autonomous Region. The survey covered 50 counties (cities) and 156 townships (towns), resulting in a total of 3830 completed household survey questionnaires.

3.2. Research Method

This study will first utilize the empirical analysis framework based on ordinary least squares (OLS) to estimate the impact of farmers’ adoption of e-commerce on land transfer. The specific model setting is as follows:

$$Y_i = \alpha + \delta Ecommerce_i + \beta X_i + \eta_i + \varepsilon \quad (1)$$

In Equation (1), Y_i represents the dependent variable of interest in this study, indicating the situation of land transfer; $Ecommerce$ indicates whether farmers adopt e-commerce; δ represents the degree of influence of farmers’ adoption of e-commerce on land-transfer behavior; X represents other control variables; β represents the coefficients of control variables; η_i represents provincial fixed effects; and ε represents the random disturbance term.

In reality, rural households carry out various behaviors related to land transfer as the result of subjective initiative, not a random event. The individual characteristics of households and family characteristics will also affect the behavior of farmers related to land transfer. If we ignore these potential factors, the resulting estimates are biased. To overcome the sample selection problem, this study introduces propensity score matching (PSM). The core idea of PSM is to match farmers who adopt e-commerce and those who do not based on observed farmer characteristics, ensuring that the two groups of farmers are in a balanced and comparable state. Subsequently, the differences in land management behaviors between the two groups of farmers are further compared. Specifically, the propensity score obtained by farmers participating in e-commerce is the probability of farmers participating in e-commerce under certain conditions. Before calculating the impact of e-commerce adoption on land market development, it is necessary to calculate the propensity score matching values based on the probit model. The specific model setting is as follows:

$$P(Z_i) = P(Ecommerce = 1|Z_i) = \Lambda(Z_i'\beta) = \exp(Z_i'\beta) / (1 + \exp(Z_i'\beta)) \quad (2)$$

In Equation (2), $P(Ecommerce = 1|Z_i)$ represents the propensity score matching value for farmers participating in e-commerce, where Z_i is the matching variable. After calculating the propensity score matching values, various matching methods can be used to match farmers who adopt e-commerce with those who do not. This study employs methods such as 1:1 nearest neighbor matching, kernel matching, and radius matching. Once the matching is completed, the impact of farmers’ adoption of e-commerce on land market development can be assessed. Typically, the average treatment effect of the treated (ATT)

is calculated to characterize the impact of farmers' adoption of e-commerce. The specific model setting is as follows:

$$ATT = E(Y_1|Ecommerce = 1) - E(Y_0|Ecommerce = 1) = E(Y_1 - Y_0|Ecommerce = 1) \quad (3)$$

In Equation (3), Y_1 represents the land transfer status of farmers who adopt e-commerce, and Y_0 represents the land transfer status of farmers who do not adopt e-commerce.

3.3. Variable Selection and Description

Dependent variable: The dependent variable of interest in this study is the situation of land transfer, mainly characterized by two categories of indicators. The first category is the participation of farmers in land transfer, including whether farmers engage in land transfer (1 = yes; 0 = no), whether they engage in land transfer in (1 = yes; 0 = no), the scale of land transfer in (in mu), whether they engage in land transfer out (1 = yes; 0 = no), and the scale of land transfer out (in mu). The second category is the market-oriented behavior of land transfer, including whether farmers have signed written agreements (1 = yes; 0 = no), whether they have specified the lease term (1 = yes; 0 = no), whether they receive or pay monetary rent (1 = yes; 0 = no), and whether they rent land to acquaintances or rent land from acquaintances (1 = yes; 0 = no).

Core explanatory variable: Referring to previous measures of farmers' adoption or participation in agricultural e-commerce [39], the core explanatory variable of interest in this study is measured by whether farmers operate products through online transactions at home (1 = yes; 0 = no). According to the descriptive statistical analysis of variables (Table 1), 6.3% of the 3726 farming households sell their agricultural products online.

Table 1. Descriptive statistics for variables.

Variable	Variable Description	Sample Size	Mean	Std.
Dependent Variables				
Land Transfer	1 = Yes, 0 = No	3627	0.536	0.499
Land Transfer Out	1 = Yes, 0 = No	3595	0.324	0.468
Written Agreement	1 = Yes, 0 = No	1133	0.643	0.475
Clearly Defined Lease Term	1 = Yes, 0 = No	1133	0.605	0.489
Cash Rent Collection	1 = Yes, 0 = No	1002	0.965	0.184
Transfer to Acquaintances	1 = Yes, 0 = No	905	0.534	0.499
Land Transfer In	1 = Yes, 0 = No	3580	0.249	0.432
Written Agreement	1 = Yes, 0 = No	885	0.349	0.477
Clearly Defined Lease Term	1 = Yes, 0 = No	881	0.359	0.480
Cash Rent Payment	1 = Yes, 0 = No	646	0.952	0.214
Transfer from Acquaintances	1 = Yes, 0 = No	849	0.802	0.399
Core Explanatory Variable				
E-commerce Adoption	Whether products are sold online; 1 = Yes, 0 = No	3726	0.063	0.243
Control Variables				
Gender of Household Head	1 = Male; 0 = Female	3827	0.934	0.248
Education of Household Head	1 = High school and above; 0 = Below high school	3830	0.152	0.359
Age of Household Head	Year	3816	55.019	11.236
Ethnicity of Household Head	1 = Han ethnicity; 0 = Minority ethnicity	3830	0.875	0.330
Household Head as Village Cadre	1 = Yes, 0 = No	3830	0.070	0.255
Number of Labor Force in Family	Population aged 14–64	3830	2.863	1.338
Proportion of Children in Family	Proportion of the population under 14	3540	0.265	0.426
Proportion of Elderly in Family	Proportion of the population over 64	3540	0.198	0.408

Control variables: To further eliminate the potential influence of omitted factors, drawing on previous research [12,40], this paper also controls for individual characteristics

of farmers (such as gender of household head, education, age, ethnicity, and holding village cadre positions) as well as household characteristics (such as the proportion of children, the proportion of elderly, and the number of labor force). These control variables were chosen with the following considerations in mind: when the head of the household is more educated, he or she has more opportunities for off-farm employment, is better financed, and is more likely to transfer land. When the household head is older, he or she has reduced physical strength and is, therefore, less likely to transfer land. Considering that the increase in the number of children under the age of 14 and the number of elderly people over the age of 64 creates a burden on households, it is expected that these households will be less likely to lease land. However, when the farmer has a larger number of household laborers, the head of the household is a man or a village cadre, they are more likely to lease land. Additionally, this study also controls for provincial fixed effects in empirical estimation.

Table 2 reveals that the proportion of land transfer among farmers who adopt e-commerce is slightly higher than those who do not. As Figure 2 shows, farmers who adopt e-commerce have significantly higher proportions of land transfer in and larger areas of acquired land compared to those who do not adopt e-commerce. As Figure 3 shows, the proportion of land transfer and the area of land transferred among farmers who adopt e-commerce are slightly lower than those who do not.

Table 2. Preliminary relationship between farmers’ e-commerce adoption and farmland-transfer behavior.

E-Commerce Adoption	Land Transfer	Land Transfer In	Land Transfer In Area	Land Transfer Out	Land Transfer Out Area
Adoption	0.570	0.372	40.245	0.273	1.917
Non-Adoption	0.531	0.245	11.404	0.323	2.278
Difference	0.039	0.127 ***	28.841 ***	−0.050	−0.361

Note: *** indicates significance at the 1% level.

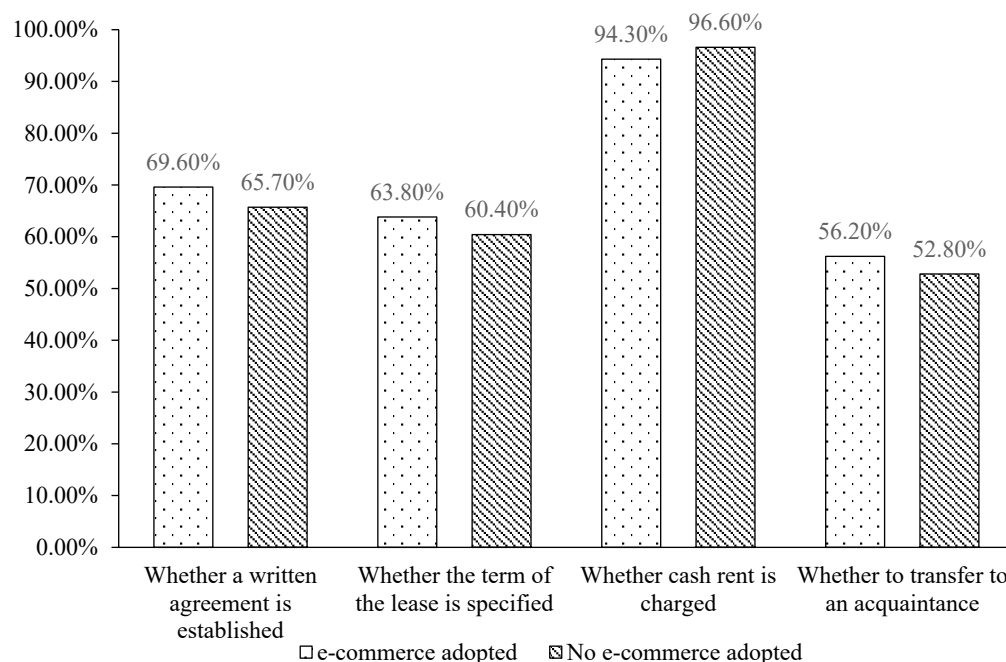


Figure 2. Marketability of land turnout under different e-commerce adoption.

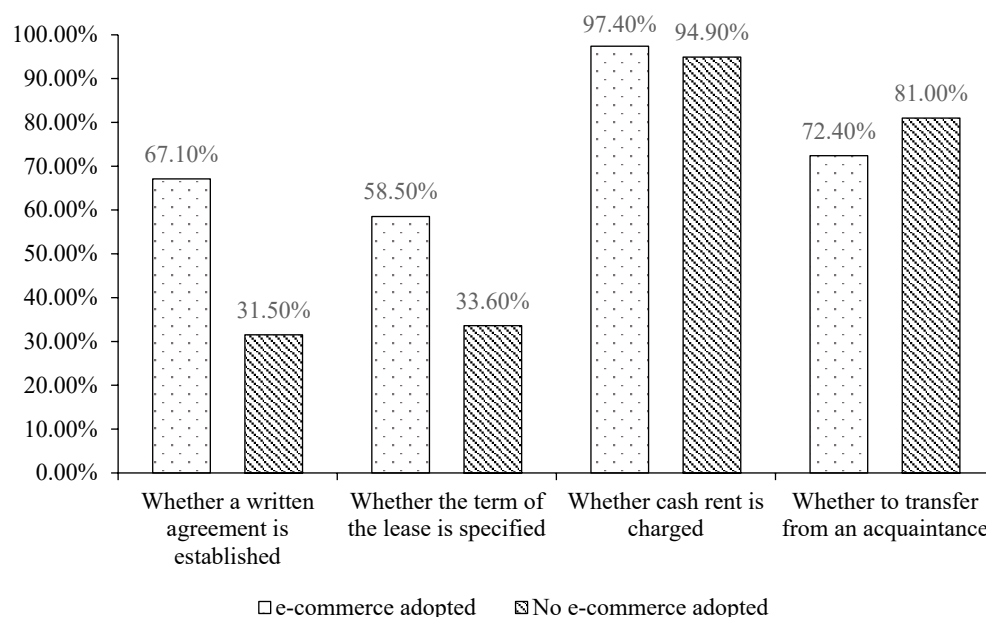


Figure 3. Marketization status of land transfers under different e-commerce adoption.

4. Results

4.1. Baseline Regression

This paper initially explores the impact of farmers’ adoption of e-commerce on their participation in land-transfer behavior based on the framework of ordinary least squares (OLS) empirical analysis. The estimation results in Table 3 demonstrate that the adoption of e-commerce by farmers has a significant impact on their participation in land transfer, primarily manifested in promoting farmers’ acquisition of land, leading to an 11.1% increase in the probability of leasing land. The adoption of e-commerce by farmers increases the probability of renting land by 11.1 percent, with an average probability of land transfer of 24.9%, making this result economically significant. However, the baseline regression results did not reveal a significant impact of farmers’ adoption of e-commerce on their land-transfer-out behavior.

Table 3. The impact of farmers’ adoption of e-commerce on their participation in land transfer.

Explanatory Variables	Dependent Variables:		
	Land Transfer (1 = Yes; 0 = No) (1)	Land Transfer In (1 = Yes; 0 = No) (2)	Land Transfer Out (1 = Yes; 0 = No) (3)
E-commerce Adoption	0.052 (1.47)	0.111 *** (3.63)	−0.020 (−0.62)
Gender of Household Head	0.048 (1.52)	0.169 *** (5.27)	−0.097 ** (−2.87)
Education of Household Head	−0.041 (−1.65)	−0.094 *** (−4.33)	0.035 (1.56)
Age of Household Head	−0.001 (−1.29)	−0.005 *** (−5.72)	0.004 *** (4.11)
Ethnicity of Household Head	0.04 (1.54)	0.046 * (2.00)	−0.003 (−0.13)
Household Head as Village Cadre	−0.049 (−1.41)	0.003 (0.09)	−1.83 (0.019)
Proportion of Children under 14 in Family	−0.059 * (−2.27)	−0.058 * (−2.53)	0.009 (0.39)
Proportion of Elderly over 64 in Family	−0.013 (−0.61)	−0.0189 (−0.99)	0.003 (0.15)
Number of Labor Force in Family	−0.016 (−1.84)	0.007 (0.95)	−0.026 ** (−3.10)
Provincial Fixed Effects	controlled	controlled	controlled
Observations	3260	3246	3246
R-squared	0.006	0.015	0.015

Notes: (1) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; (2) T-values are shown in parentheses.

4.2. Robustness Analysis

4.2.1. Replacement of Dependent Variables

In order to test the robustness of the baseline model, this paper firstly replaces the explanatory variables with land area of transferred in and transferred out to estimate the model. The results are shown in Table 4. From the estimation results, it can be observed that after replacing the dependent variables, the adoption of e-commerce by farmers has a significant positive impact on the area of land transferred in. Specifically, the adoption of e-commerce by farmers leads to a significant increase in the area of land transferred in by over 26 mu. However, the impact on the area of land transferred out is not significant. This is consistent with the results of the baseline regression.

Table 4. The impact of farmers' adoption of e-commerce on the area of land transferred.

Explanatory Variables	Dependent Variables:	
	Land Transferred In Area (1)	Land Transferred Out Area (2)
E-commerce Adoption	26.010 *** (4.96)	−0.035 (−0.06)
Gender of Household Head	8.369 (1.52)	−0.051 (−0.08)
Education of Household Head	−0.467 (−0.13)	0.488 (1.10)
Age of Household Head	−0.555 *** (−4.00)	0.055 ** (3.29)
Ethnicity of Household Head	7.276 (1.87)	0.377 (0.80)
Household Head as Village Cadre	6.753 (1.29)	−0.860 (−1.37)
Proportion of Children under 14 in Family	−3.067 (−0.79)	−0.531 (−1.13)
Proportion of Elderly over 64 in Family	−3.011 (−0.93)	−1.035 ** (−2.66)
Number of Labor Force in Family	−0.311 (−0.23)	−0.634 *** (−3.96)
Provincial Fixed Effects	controlled	controlled
Observations	3229	3246
R-squared	0.033	0.009

Notes: (1) *** $p < 0.01$, ** $p < 0.05$; (2) T-values are shown in parentheses.

4.2.2. Propensity Score Matching

In the second step of the robustness test in this paper, the impact of farmers' adoption of e-commerce on their participation in land transfer is validated through propensity score matching. To ensure the quality of matching between the 'treatment group' and the 'control group' in propensity score matching, it is necessary to check the common support conditions of the matching. If the common support is too narrow, it will result in too much sample loss and ineffective matching. The common support requires that there is sufficient overlap between the propensity score values of the 'treatment group' and the 'control group', i.e., there should be a substantial 'common support domain'. This paper further calculates the sample loss under different propensity score methods to determine how many samples have propensity score values within the common support domain. Under 1:1 nearest neighbor matching, kernel matching, and radius matching, when the dependent variables of interest are whether to engage in land transfer, whether to transfer in land, transfer in area, whether to transfer out land, transfer out area, and land operating area, the sample loss is between 5% and 6%. This means that there are enough samples with propensity score matching values within the common support domain. Therefore, it is reasonable to believe that the estimation bias caused by the lost samples is very small.

Given the differences between farmers who adopt e-commerce and those who do not at the individual and household levels, as evidenced in the results before matching in Table 5, it is clear that there are significant differences in endowment characteristics between these two types of farmers. Such differences may introduce biases in the estimation when using the least square method. After matching, except for the variable ‘transfer to acquaintances’, the standardized biases of other explanatory variables are all less than 10%, with many variables showing standardized biases of less than 3%. This is significantly lower than the standardized biases before matching. Additionally, it can be observed that the differences in endowment characteristics between the ‘treatment group’ and the ‘control group’ have shifted from significant before matching to non-significant after matching. These results indicate that the matched samples have similar characteristics, and the overall bias has been significantly reduced, thus passing the balance test.

Table 5. Balance test results of dependent variables before and after matching.

Dependent Variable	Matching Status	Pseudo R ²	LR Statistic	p-Value	Mean Bias
Land Transfer	Before Matching	0.028	44.68	0.000	17.900
	After Matching	0.005	2.740	0.841	4.500
Land Transfer In	Before Matching	0.027	43.38	0.000	17.300
	After Matching	0.000	0.220	1.000	1.500
Transfer In Area	Before Matching	0.027	43.38	0.000	17.300
	After Matching	0.000	0.220	1.000	1.500
Land Transfer Out	Before Matching	0.029	45.91	0.000	18.100
	After Matching	0.003	1.920	0.927	4.300
Transfer Out Area	Before Matching	0.041	70.96	0.000	18.200
	After Matching	0.002	1.530	0.997	2.800
Sign Written Lease In	Before Matching	0.022	11.91	0.008	24.200
	After Matching	0.007	1.540	0.673	9.900
Specify Lease Term	Before Matching	0.022	12.00	0.007	24.400
	After Matching	0.004	1.40	0.705	9.400
Pay Cash Rent	Before Matching	0.016	7.30	0.063	19.500
	After Matching	0.001	0.20	0.978	1.700
Transfer to Acquaintances	Before Matching	0.018	8.840	0.032	22.100
	After Matching	0.004	00.90	0.826	7.800
Sign Written Lease Out	Before Matching	0.050	21.50	0.001	26.500
	After Matching	0.005	0.840	0.991	5.300
Specify Lease Term	Before Matching	0.046	20.30	0.002	25.600
	After Matching	0.008	1.190	0.977	6.100
Collect Cash Rent	Before Matching	0.048	19.28	0.004	25.400
	After Matching	0.012	1.660	0.948	9.100
Transfer to Acquaintances	Before Matching	0.056	20.12	0.003	27.500
	After Matching	0.024	3.070	0.800	11.900

Notes: The propensity score matching method used in the table is 1:1 nearest neighbor matching. The paper also conducted balance tests using kernel matching and radius matching methods, and the results are highly consistent with the conclusions in Table 5. Due to space limitations, they are not presented here.

Therefore, both the common support test and the balance test are passed, indicating that the estimation results obtained based on propensity score matching are reliable.

Table 6 presents the results using 1:1 nearest neighbor matching, kernel matching, and radius matching. The results show that the adoption of e-commerce by farmers does not have a robust positive significant effect on their participation in land transfer or land transfer out. However, the adoption of e-commerce by farmers has a significant positive effect on their land transfer in and the increase in transfer in area, both at the 1% significance level. Moreover, there is no significant difference in the magnitude of the coefficients compared to the estimates from ordinary least squares. Overall, the conclusions from Table 6 further confirm the significant promoting effect of farmers’ adoption of e-commerce on their participation in land transfer.

Table 6. Effects of farmers’ adoption of e-commerce on their participation in land transfer under propensity score matching (PSM).

Dependent Variable	Adoption of E-Commerce	1:1 Nearest Neighbor Matching	Kernel Matching	Radius Matching
Land Transfer	Adopt E-commerce	0.577	0.577	0.577
	Not Adopt E-commerce	0.523	0.519	0.520
	Difference	0.055	0.058 *	0.057
Land Transfer In	Adopt E-commerce	0.376	0.376	0.376
	Not Adopt E-commerce	0.256	0.259	0.260
	Difference	0.119 ***	0.117 ***	0.115 ***
Transfer In Area	Adopt E-commerce	41.050	41.050	41.050
	Not Adopt E-commerce	11.492	13.114	13.140
	Difference	29.558 ***	27.936 ***	27.910 ***
Land Transfer Out	Adopt E-commerce	0.277	0.277	0.277
	Not Adopt E-commerce	0.329	0.295	0.294
	Difference	−0.052	−0.018	−0.017
Transfer Out Area	Adopt E-commerce	1.938	1.938	1.938
	Not Adopt E-commerce	2.138	1.994	1.986
	Difference	−0.200	−0.064	−0.048

Notes: (1) *** $p < 0.01$, * $p < 0.1$. (2) The estimated results in the table are the Average Treatment Effects (ATT).

4.3. Heterogeneity Analysis

4.3.1. Individual Heterogeneity Analysis

Previous regressions treated farmers as homogeneous individuals. However, in reality, farmers with different characteristics may exhibit heterogeneity in their adoption of e-commerce. According to other studies, farmers’ education level and whether they are engaged in non-agricultural employment often influence their land-transfer behavior [22,41–43]. Therefore, this section will focus on the heterogeneity effects of farmers’ education level and employment status. Education level is divided into two groups: low-education-level group (below high school) and high-education-level group (high school and above); employment status is divided into off-farm employment and agricultural employment. The results of the heterogeneity tests for the two groups are shown in Tables 7 and 8, respectively.

Table 7. Heterogeneity analysis based on educational levels.

Dependent Variable	Land Transfer		Land Transfer in		Land Transfer out	
	Low-Educated (1)	High-Educated (2)	Low-Educated (3)	High-Education (4)	Low-Educated (5)	High-Educated (6)
E-commerce Adoption	0.112 *** (2.73)	−0.082 (−1.19)	0.135 *** (3.69)	0.070 (1.25)	0.024 (0.62)	−0.124 * (−1.91)
Control Variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Observations	2737	512	2717	509	2725	510
R-Squared	0.008	0.036	0.035	0.033	0.017	0.026

Notes: (1) *** $p < 0.01$, * $p < 0.1$; (2) Values in parentheses are t-values.

As shown in Table 7, the adoption of e-commerce has a greater impact on the participation of low-educated farmers in land transfer, significantly promoting this group to engage in land transfer. Specifically, it positively encourages this group to acquire land, and the effect is significant at the 1% level. However, the effect on the participation of highly educated farmers in land transfer is relatively minor, only reducing the probability of these farmers transferring out land at the 10% level. This could be because highly educated

farmers, compared to low-educated ones, have a higher level of cognitive understanding, possess more knowledge about markets and sales, and have stronger skills. Hence, the marginal utility brought about by the adoption of e-commerce is relatively lower for them.

Table 8. Heterogeneity analysis based on employment status.

Dependent Variable	Land Transfer		Land Transfer in		Land Transfer out	
	Off-Farm Employment (1)	Agricultural Employment (2)	Off-Farm Employment (3)	Agricultural Employment (4)	Off-Farm Employment (5)	Agricultural Employment (6)
E-commerce Adoption	0.091 *	0.026	31.946 ***	20.894 **	−0.001	−0.027
Control Variables	(1.87)	(0.52)	(5.56)	(2.43)	(−0.00)	(−0.03)
Observations	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
R-Squared	1391	1854	1375	1847	1386	1845
	0.017	0.010	0.040	0.024	0.012	0.014

Notes: (1) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; (2) Values in parentheses are t-values.

Table 8 shows that the adoption of e-commerce has a significant positive impact on off-farm employed farmers in terms of land transfer and land transfer in. This might be due to the fact that farmers with off-farm employment in their work have higher incomes compared to full-time agricultural farmers and, therefore, have a higher budget to invest in more land for agricultural production, which aligns with hypothesis 1. Meanwhile, the result is economically significant as e-commerce adoption increases the probability of low-education-level farmers renting land by 13.5%.

4.3.2. Regional Heterogeneity Analysis

Due to the disparities in development among different provinces in China, the impact of rural household e-commerce adoption on their participation in land transfer may vary across different regions. According to previous understanding, economically developed provinces typically have better communication infrastructure, which leads to faster dissemination of information even before the adoption of rural e-commerce. Moreover, these provinces often exhibit a higher degree of implementation of government policies related to land, reducing the likelihood of further influence from rural e-commerce adoption. Conversely, this might not be the case in central and western regions. Among the ten sampled provinces in this study, Heilongjiang, Henan, and Anhui belong to the central region; Zhejiang, Shandong, and Guangdong belong to the eastern region; and Sichuan, Guizhou, Shaanxi, and Ningxia belong to the western region. After the regional delineation, regional heterogeneity analysis is conducted.

Among the 3830 surveyed rural households, a total of 1928 households engaged in land transfer, as shown in Table 9. Columns (1) to (3) indicate that in central and western regions, rural household e-commerce adoption significantly promotes land transfer, while it has no significant effect in the eastern region. The specific impact can be observed in columns (4) to (9): the probability of a household farmer adopting e-commerce transferring in land increased significantly in both the central and western regions, by 13.5 percent and 18.6 percent, respectively, whereas rural households in the eastern region do not experience a significant impact. This indicates that the influence of e-commerce adoption on land-transfer behavior among rural households in the eastern region is lower compared to those in the central and western regions, which aligns with our hypothesis. This means that in the eastern part of the country, the economy and the market are more developed, and the education level of farmers is higher, which means that agricultural e-commerce adoption plays a very limited role in mitigating information asymmetry. Meanwhile, due to the average probability of farmland transfer in being 24.9%, this result also has economic significance.

Table 9. Regional heterogeneity analysis based on region.

Dependent Variable	Land Transfer			Land Transfer in			Land Transfer out		
	Eastern (1)	Central (2)	Western (3)	Eastern (4)	Central (5)	Western (6)	Eastern (7)	Central (8)	Western (9)
E-commerce Adoption	−0.020 (−0.32)	0.118 * (1.77)	0.094 * (1.71)	0.035 (0.74)	0.135 ** (2.12)	0.186 *** (4.04)	−0.040 (−0.67)	0.064 (1.05)	−0.043 (−0.85)
Control Variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Observations	845	975	1429	921	1029	1518	842	967	1426
R-Squared	0.030	0.035	0.006	0.023	0.097	0.033	0.045	0.028	0.013

Notes: (1) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$; (2) Values in parentheses are t-values.

4.4. Further Analysis

Having established that e-commerce adoption significantly promotes rural households' engagement in land transfer, a natural extension of the inquiry arises: does rural household e-commerce adoption act as a driver for land transfer toward marketization? This paper further explores this question empirically based on research data.

Four dimensions are employed to measure the degree of marketization of land transfer: whether a written agreement is signed, whether the lease term is clearly defined, whether monetary rent is used, and whether the transferee is an acquaintance. These are used as dependent variables, focusing on rural households engaging in land transfer. The empirical analysis based on least squares method results (Table 10) indicates that rural household e-commerce adoption significantly facilitates land transfer toward marketization.

Table 10. Impact of e-commerce adoption on land-transfer marketization.

	Signed Agreement (1)	Defined Lease Term (2)	Monetary Rent (3)	Transferee (4)
E-commerce Adoption	0.336 *** (6.19)	0.228 *** (4.09)	0.027 (1.03)	−0.067 * (−1.68)
Control Variables	Controlled	Controlled	Controlled	Controlled
Observations	855	851	631	823
R-Squared	0.085	0.045	0.053	0.030

Notes: (1) *** $p < 0.01$, * $p < 0.1$; (2) Values in parentheses are t-values.

Specifically, rural households adopting e-commerce are 33.6% more likely to sign agreements and 22.8% more likely to define lease terms, with these effects being significant at the 1% level. Moreover, e-commerce adoption leads to a significant 6.7% decrease in the probability of land transfer with acquaintances, significant at the 10% level. These findings reveal that when rural households adopt e-commerce to sell products, they tend to engage in more market-oriented transfer behaviors, thus propelling China's rural land market towards standardization and contractualization.

Further estimation of the impact of rural household e-commerce adoption on the marketization of land transfer was conducted using propensity score matching. The results are presented in Table 11.

The conclusions drawn from 1:1 nearest neighbor matching, kernel matching, and radius matching methods support the results obtained from OLS estimation, indicating that e-commerce adoption enhances the probability of rural households engaging in land transfer through more contractual and modernized means. Specifically, for rural households involved in land transfer, e-commerce adoption significantly increases the probability of signing written agreements and defining lease terms. Moreover, under 1:1 nearest neighbor matching, there is a significant increase in the probability of rural households paying cash rent when acquiring land.

Table 11. Impact of rural household e-commerce adoption on marketization of land-transfer behavior under PSM.

Explained Variable	E-Commerce Adoption	1:1 Nearest Neighbor Matching	Kernel Matching	Radius Matching
Signed Agreement	Adopt E-commerce	0.718	0.718	0.718
	Not Adopt E-commerce	0.535	0.436	0.439
	Difference	0.183 **	0.282 ***	0.280 ***
Defined Lease Term	Adopt E-commerce	0.620	0.620	0.620
	Not Adopt E-commerce	0.501	0.459	0.471
	Difference	0.119 *	0.151 **	0.149 **
Monetary Rent	Adopt E-commerce	0.972	0.972	0.972
	Not Adopt E-commerce	0.895	0.951	0.951
	Difference	0.077 **	0.021	0.020
Transferee Acquaintance	Adopt E-commerce	0.718	0.718	0.718
	Not Adopt E-commerce	0.734	0.760	0.759
	Difference	−0.015	−0.042	−0.041

Notes: (1) *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. (2) The estimated results in the table are the Average Treatment Effects (ATT).

5. Discussion

5.1. Conclusions and Discussion

The continuous development of rural factor markets is a central part of rural transformation, and land factors are an important part of rural factor markets. Therefore, exploring how the adoption of new technologies contributes to the factorization of agricultural land is an important prerequisite for understanding how the process of rural transformation takes place. This study, based on data from the Comprehensive Rural Revitalization Survey (CRRS) conducted by the Chinese Academy of Social Sciences, investigates the impact of rural household e-commerce adoption on land transfer. Utilizing both ordinary least squares (OLS) and propensity score matching (PSM) methods, empirical results demonstrate that rural household e-commerce adoption significantly facilitates land transfer by promoting both the likelihood and the scale of land influx. Moreover, rural household e-commerce adoption enhances the marketization of rural land transfer by increasing the probability of signing written agreements, defining lease terms, and transferring land to strangers. This indicates a shift towards more contractual and standardized practices in the rural land-transfer market. Additionally, regional heterogeneity analysis reveals that the influence of rural household e-commerce adoption on land transfer is more pronounced in the central and western regions compared to the eastern region. Furthermore, individual heterogeneity analysis indicates that households with lower education levels and engaged in non-agricultural activities are more likely to participate in land transfer after adopting rural e-commerce.

5.2. Policy Recommendations

The policy implications of this article are as follows. Firstly, as of 2020, only 6.3% of Chinese rural households utilize e-commerce channels to sell agricultural products, indicating significant room for improvement in agricultural product sales through e-commerce channels. China's digital infrastructure is now very well developed, with the world's largest fiber-optic network and the world's largest 5G network in terms of speed and scale [44]. In the context of the digital economy, the ability to use e-commerce platforms to increase incomes depends largely on the digital literacy of farmers. Therefore, further expansion of rural e-commerce needs to strengthen the capacity of farmers to utilize emerging technologies [45,46]. Secondly, while e-commerce adoption can facilitate the transfer of agricultural land and lead to further concentration of agricultural land, it may further induce new inequalities. For example, previous studies have found that agriculture can play an important buffering role as a 'reservoir' when non-farm employment is hit [47,48].

When rural laborers in non-farm employment face negative economic shocks, they are likely to return to their home villages with the expectation that agricultural production will secure their daily lives. However, since land management rights have been transferred, agricultural production cannot serve as the last barrier to secure their livelihoods. Therefore, the relevant authorities should further reform China's household registration system so that peasants working in the cities can access equal public services as urban residents. Thirdly, given the differential impact of e-commerce adoption on the land-transfer behavior of farmers in different regions of China, relevant policies and resource inputs aimed at promoting e-commerce adoption among farmers should be tilted towards less developed regions.

5.3. Limitations and Future Prospects

This study has the following limitations. On the one hand, although we used PSM to identify the impact of farmers' e-commerce adoption on their land-transfer behaviors, there are still unobservable factors that both influence farmers' e-commerce adoption and land-transfer behavior. Therefore, future research can try to find a more appropriate identification strategy to carry out the analysis. On the other hand, the e-commerce adoption behaviors of farmers are not homogeneous, as some farmers apply for registration of online shops for sales, while others just post product information on social platforms to promote sales. Therefore, even if they all belong to e-commerce adoption, farmers' behaviors are different, so future research can further expand the impact of different e-commerce behaviors on land transfer.

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