

Article

Impact of Rural E-Commerce Participation on Farmers' Household Development Resilience: Evidence from 1229 Farmers in China

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Abstract: This paper investigates the impact of e-commerce participation on household development resilience using a sample of 1229 households in the Shandong and Shaanxi provinces of China in 2022. It constructs the developmental resilience index of farm households from three dimensions of economy, society and culture using the entropy method, and establishes a counterfactual framework using the Propensity Score Matching (PSM) method. The results suggest that participation in e-commerce has a significant and positive impact on farming household development resilience. The PSM method estimates that participation in e-commerce increases the developmental resilience of farming households by 9.63% compared to non-participation, with economic, social, and cultural resilience increasing by 9.29%, 9.84%, and 9.92%, respectively. The robustness test results confirm the findings. Further analysis reveals that participation in e-commerce enhances farm household development resilience through three mechanisms: improving economic efficiency, network relationship linkage, and risk appetite. Heterogeneity analysis shows that the impact of e-commerce participation on household development resilience varies among farmers with different endowment constraints. In particular, farmers with more years of education and cooperative members benefit more from e-commerce participation, especially live and platform e-commerce.

Keywords: participation in e-commerce; household development resilience; network ties; economic gains; PSM model



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1. Introduction

In light of a century marked by transformative shifts and epidemics, the Chinese government should prioritize and promote the 'Three Rural Areas' initiative to ensure stable and increased agricultural production, rising incomes for farmers, and rural stability. China's agriculture and rural areas have witnessed rapid modernization, resulting in an industrial development framework, diverse income growth structures, and effective rural governance [1,2]. However, rural households in China face formidable challenges characterized by low social status, limited business capacity, and the compounded impacts of multiple disasters [3–5]. Consequently, their household incomes and livelihoods are vulnerable to uncertainty and external risks, leaving some without the resilience needed to cope with such adversities [6,7]. To tackle this issue, the government has implemented numerous relief measures, such as financial transfers, increased employment opportunities, and economic subsidies to alleviate losses caused by uncertainties in small-scale agricultural production [8,9]. Nonetheless, these measures have significant problems, including uneven resource distribution, imprecise resource targeting, and a singular mode of assistance [10,11]. The adoption of broad and all-encompassing relief approaches complicates the efficient allocation of government resources, leading to elite capture and indiscriminate waste [12,13]. Furthermore, these measures fail to address the fundamental

need for farmers to develop resistance and diversify risk capabilities to effectively manage risks. Consequently, as the main contributor to rural economic development, there is a pressing need to enhance family resilience to cope with uncertainties, abrupt changes, and unforeseen challenges. This underscores the importance of stimulating endogenous momentum in family development, thereby rendering it an urgent issue that requires concerted attention from both academia and the government.

In recent years, the deep integration and development of the Internet and the real economy have spurred a plethora of new business forms and economic models [14,15]. This progress, in turn, has provided fresh momentum for enhancing the quality and efficiency of rural economic development in the modern era [16,17]. Rural e-commerce, as the primary application of Internet technology in rural economic activities, has emerged as a crucial tool for enabling farmers to participate in the benefits of contemporary economic and social progress [18]. By reducing the entry barriers for farmers to access national and global markets with minimal search, labor, and transportation costs, rural e-commerce successfully mitigates the inherent limitations of small rural markets [19]. Furthermore, it facilitates effective connections between farmers' production and consumer markets, promoting the swift flow of rural factor resources [20]. Moreover, rural e-commerce effectively integrates market demand for agricultural products, thereby mitigating farmers' disadvantaged positions in trade participation, access to credit, and social resources. In this way, rural e-commerce bolsters the resilience of agricultural production and operations [21,22]. Particularly in the wake of China's successful eradication of absolute poverty, as the country enters a new phase of comprehensive rural revitalization and consolidates its achievements in poverty alleviation, there remains a significant risk of previously lifted rural populations falling back into poverty [23]. Hence, the government should promote the widespread adoption of rural e-commerce among low-income groups in rural areas, enabling more farmers to participate in the digital economy and share its dividends [24]. This initiative not only enhances households' inherent development capabilities but also strengthens their resilience to unforeseen shocks, serving as a vital strategy for addressing relative poverty and preventing the recurrence of poverty [25].

However, existing literature has underscored the crucial role of rural e-commerce in advancing farmers' income, entrepreneurship, and innovation [26,27], while ignoring the characteristic fact that farm households face an uncertain external environment. Only very limited number of studies have focused on the long-term impacts of rural e-commerce development. According to Wang and Zhang [28], the impact of participation in e-commerce on rural household development is uncertain in the long run. Household development resilience incorporates the uncertainty of external shocks and risks into the framework of household welfare analysis, which refers to the ability of farm households to withstand and recover from external shocks. It provides a new perspective for effectively analyzing shocks and stresses that threaten the well-being of vulnerable groups [29]. Speranza et al. link household development resilience to various livelihood capitals, such as economic, social, ecological, and human capitals, to quantify household development resilience [30]. Participation in e-commerce has been well documented in studies on the growth of farming households' economic income, but whether it will have a positive effect on other dimensions of household development resilience is yet to be demonstrated. Considering the multidimensional characteristics of household development resilience and the heterogeneous endowments of individual farmers [31]. These factors can potentially affect the impact of rural e-commerce on development resilience at the microlevel [32]. Therefore, exploring this effect requires theoretical analysis and empirical testing to measure the relationship between rural e-commerce participation and household development resilience. This measurement involves various dimensions of heterogeneity, shedding light on the heterogeneous effects of farmers' participation based on their distinct endowments.

This paper makes potential contributions in four areas. First, it establishes an indicator system for farmer household development resilience regarding economic, social, and cultural aspects at the micro-farmer level. This system enriches the construction of indicators

for subsequent quantitative research on farmer-family development resilience. Second, this study investigates the impact mechanism of farmers' households' participation in e-commerce, specifically examining its effects on their development resilience. This exploration considers economic benefits, network ties, and risk appetite as key factors affecting the observed impact. By revealing the theoretical 'black box' of rural e-commerce's effect on the development resilience of farmers' households, it enriches the research content on the impact of rural e-commerce. Third, this study adopts the Propensity Score Matching (PSM) method to estimate the impact of participation in e-commerce on the resilience of farmers' households. This approach differs from the traditional OLS method since it not only reflects whether participation in e-commerce affects the resilience of farmers' households but also measures the net effect of participation in e-commerce on the resilience of farmers' households. In addition, considering that farmers' participation in e-commerce has a self-selection problem, PSM can effectively address the selectivity bias that may be brought about by variables that have a "self-selection" problem. Fourth, the study conducts heterogeneity analysis to examine the differences in the impact of e-commerce participation on the farm households' development resilience with different endowments. This analysis clarifies the heterogeneity of the rural e-commerce impact on households' development resilience and the underlying causes. It provides policymakers with decision-making references to construct differentiated policy measures.

2. Literature Review and Research Hypotheses

2.1. Literature Review

2.1.1. Three-Dimensional Construction of Household Development Resilience

The term 'resilience', derived from the Latin language, has gained widespread usage in various fields, including psychology, sociology, and economics [32,33]. Its application has now expanded to domains like rural revitalization, poverty alleviation, and agricultural insurance, providing new research ideas and empirical evidence for the study of rural areas [34,35]. Currently, numerous scholars have studied household development resilience using different approaches and methods. However, most scholars have adopted the comprehensive indicator evaluation method to portray household responses to shocks or highlight differences in responses across dimensions [8]. For instance, Wang et al. employed a sustainable livelihood strategy analysis framework to categorize household development resilience into production, ecological, and economic resilience [36]. Hao and Tan measured household development resilience in terms of resistance, resilience, and reconstruction [37]. Nevertheless, an increasing number of scholars criticize the direct application of ecological analytical frameworks to economic analysis [38,39]. Walker et al. identified that the resilience analytical framework developed based on ecology may not appropriately capture and reflect dynamic socio-economic characteristics, especially the structure of economic agents responding to the reorganization of external shocks, system renewal, and ecological feedback [40]. This limitation restricts the prediction of future economic phenomena.

As research in this area continues to deepen, the concept of household development resilience has evolved into a multidimensional one, owing to the increasing diversification of risks and uncertainties confronting families. According to Tung et al. and Li et al. [41,42], family development resilience is rooted in the family's own initiative, based on their pursuit of opportunities and risk avoidance. It emerges as a product of the family's strategy, and diverse paths of family transformation contribute to the varying development resilience among farmers' families [36]. McManus et al. argued that the developmental resilience of farming families encompasses mainly economic, social, and cultural elements, a viewpoint corroborated by other scholars [43]. Huang et al. further identified the developmental resilience of the family as comprising three main components: economic resilience, social resilience, and cultural resilience [44]. Economic resilience principally refers to the ability to expand employment channels, tap into income sources, and resist family risks [7]. Social resilience involves the ability to forge social networks, share social information, and trust

the community [45,46]. Cultural resilience encompasses the ability to break away from poverty mindsets and learn from environmental changes [47]. On this basis, this paper constructs a three-dimensional model of family development resilience encompassing economic resilience, social resilience, and cultural resilience.

2.1.2. Rural Electric Commerce (REC)

In the context of rural e-commerce development, scholars concur that, in a narrow sense, rural e-commerce refers to the utilization of internet platforms for rural network marketing in specific environments [48]. However, in a broader sense, rural e-commerce entails the integration of all stages in agricultural production-supply-marketing, including production, transportation, and consumer consumption, intending to achieve income for farmers, profits for practitioners, and benefits for consumers [49]. In contrast to traditional agricultural product sales channels, rural e-commerce can leverage various platforms, including social media, trading websites, and e-commerce platforms. It primarily encompasses two models: traditional e-commerce and social e-commerce [26,50]. Rural e-commerce provides agricultural producers with the opportunity to overcome geographical limitations in the sale of agricultural products and access a broader market, thereby increasing farmers' income [51,52]. For consumers, the product screening and display mechanisms of rural e-commerce on e-commerce platforms facilitate the purchase of high-quality and affordable agricultural products, addressing challenges arising from geographical constraints on production and marketing [53,54].

2.2. Research Hypotheses

2.2.1. Impact of Participation in E-Commerce on Household Development Resilience

Rural e-commerce plays a pivotal role in economic activity within rural areas, transcending spatial and temporal constraints while enhancing transaction efficiency and speed for farmers [54]. Its widespread adoption fosters a deep integration of information technology and economic endeavors in rural regions, emerging as a pivotal factor driving regional economic advancement [55,56]. First, a resilient and adaptable economy demonstrates its ability to withstand significant external disruptions. Engaging in rural e-commerce not only creates fresh employment prospects and broadens income streams for farmers through labor but also effectively boosts their earnings from sales of agricultural products [57–59], thereby bolstering household resilience. Secondly, the e-commerce platform serves as a central hub for information exchange, facilitating interactions with business partners and allowing farmers to communicate with industry peers both locally and beyond. This communication paves the way for accessing crucial market intelligence, policy updates, and ample business resources essential for household development [50], which significantly enhances household resilience. The varied cognitive levels and behavioral patterns of farm households may, in part, stem from entrenched traditional beliefs, customs, and informal systems, potentially leading to cognitive pitfalls [60,61]. However, participation in rural e-commerce introduces farmers to new thought patterns and provides a broader exposure to accurate external ideas, fostering a shift away from erroneous social perceptions [62–64]. This transformation contributes to more adaptable behaviors in production and life, effectively mitigating the impact of uncertain risks and ultimately bolstering household development resilience. Based on this analysis, this paper proposes Hypothesis 1:

H1. *Participation in rural e-commerce can significantly increase household development resilience.*

H1a. *Participation in rural electricity can significantly increase the economic resilience of farming households.*

H1b. *Participation in rural e-commerce can significantly increase the social resilience of farming households.*

H1c. *Participation in rural electricity can significantly increase the cultural resilience of farming households.*

2.2.2. Mediating Role of Economic Gains

Participation in rural e-commerce can effectively enhance the economic benefits of farming households [65,66]. This is achieved through various channels, including increasing employment opportunities and agricultural income, which significantly improves the resilience of farming households [67]. Rural e-commerce can increase the employment opportunities of farmers and help them diversify the risks of family production and operation by improving non-farm economic income [68]. This improves the overall level of welfare among farmers' families and enhances the resilience of their development. With the rapid development of rural e-commerce, many new forms and modes of business have emerged, providing more employment opportunities for rural residents and driving farm households to engage in non-farm production under the employment of digital capital for the accumulation of family wealth [20,56]. Farmers can participate in e-commerce jobs to engage in self-employment economic activities, enhancing the family's economic efficiency and dispersing economic risks.

Furthermore, participation in e-commerce broadens market channels, improves the stability and predictability of agricultural product sales, and increases the agricultural business income of farming households [58], significantly enhancing their development resilience. The e-commerce platform builds a one-to-one docking channel between farmers and consumers, effectively alleviating the problem of information asymmetry in production and marketing while expanding consumer choices of commodities and lowering the costs of selling agricultural products and transaction costs [58,69]. Farmers with a competitive advantage in high-quality agricultural products can effectively improve the market price of their goods by leveraging detailed product displays and the incentive mechanisms of a good reputation provided by the e-commerce platform [70,71]. This contributes to a significant increase in the farmers' agricultural income, enhancing household development resilience [72]. Based on this explanation, this study proposes Hypothesis 2:

H2. *Participation in e-commerce enhances household development resilience by boosting their economic gains.*

2.2.3. Mediating Role of Network Ties

Participation in e-commerce effectively strengthens farmers' social connections [73], thereby bolstering farming families' resilience in two key ways. Firstly, engaging in e-commerce widens the reach of farmers' social networks [74]. Typically, farmers' social connections are confined within their local village communities due to limited resources [75,76]. However, the proliferation of rural e-commerce has provided farmers with opportunities to forge new online social ties, expanding their network beyond traditional boundaries [77,78]. This expansion facilitates the seamless spread of technological know-how and digital skills among farmers, fostering the farming households' welfare and development capacity [79,80]. Secondly, e-commerce participation enables farm households to access a broader range of information and knowledge across different geographical areas [81]. Rural residents often have limited exposure to new knowledge and skills due to the closed nature of regional information. Through e-commerce, farm households can receive and exchange information with greater precision and transparency, obtaining targeted resources related to employment, technology, and skills at a reduced cost [82]. This, in turn, significantly fortifies the resilience of household development. According to this analysis, this paper posits Hypothesis 3.

H3. *Participation in e-commerce enhances household development resilience by improving their network relational linkages.*

2.2.4. Mediating Role of Risk Appetite

Participating in rural e-commerce effectively enhances farmers' risk appetite, thereby bolstering the resilience of their family development in two key aspects. Firstly, farmers face various types of risks, such as natural, market, and technological risks, during agricultural production. Due to limited access to information, most farmers tend to be risk-averse [83,84]. However, active participation in rural e-commerce empowers farmers to leverage information technology to promptly comprehend market dynamics, employment opportunities, and potential profits [85]. This understanding enables them to analyze business strategies from multiple perspectives and levels with precision, thus continuously improving their risk appetite. Farmers with a higher risk appetite can quickly identify new market opportunities, seize evolving market conditions, and make informed decisions, ultimately enhancing the farming families' resilience [86,87]. Secondly, agriculture frequently faces the dual pressures of natural and market risks, and the decentralized structure of small-scale farming limits farmers' ability to effectively cope with and withstand risks [88]. Participating in e-commerce allows farmers to establish fruitful cooperative relationships with enterprises, cooperatives, and other emerging business organizations [89]. Through these alliances, farmers not only enhance the market competitiveness of their agricultural products by leveraging collective bargaining advantages but also increase their risk appetite through technical guidance and information consultation [90]. Farmers with a higher risk appetite are more inclined to pursue potentially higher returns through risky investments [91,92]. Although this may lead to more assertive management of household affairs, the social network connections and increased returns derived from such investments serve as important drivers stimulating the farming households' development, thus significantly improving their resilience. Hence, this paper proposes Hypothesis 4.

H4. Participation in e-commerce enhances household development resilience by increasing farmers' risk appetite.

3. Data and Methods

3.1. Data

The research data are mainly sourced from a sampling survey conducted by the project "The impact of digital technologies to enhance the household development capacity", which is the Shandong Province Social Science Planning Project, China. This project team conducted a rural field household survey between July and September 2022 in Shandong and Shaanxi provinces in China. The survey team employed a stratified random sampling approach. Firstly, Shandong and Shaanxi provinces were individually selected due to their significance as major apple-producing regions. Secondly, specific areas within each province were chosen based on varying levels of economic development. In Shandong Province, the areas selected were Qixia, Penglai, and Yishui, while in Shaanxi Province, Pucheng, Liquan, and Mizhi were chosen. Within each county, 2–3 townships were selected based on their level of economic development. Finally, 2–3 natural villages were randomly chosen within each township, and 15–20 sample farmers (mainly household decision-makers involved in production and management) were randomly selected within each administrative village (community) to complete the questionnaire survey. A total of six counties (cities) were surveyed, and 1300 questionnaires were distributed. Individual questionnaires primarily collected information on respondents' personal characteristics, income, expenditure, employment, participation in the digital economy, and risk preferences. Village-level questionnaires focused on data related to village population, economic development, and industrial progression. After eliminating questionnaires with noticeable errors and missing key information, a total of 1229 valid questionnaires were retained, resulting in a questionnaire validity rate of 94.54%.

3.2. Variables

3.2.1. Dependent Variable: Household Development Resilience

Regarding the construction of a household development resilience evaluation indicator system, there are mainly two widely used analytical frameworks. One is represented by McManus et al. and Huang et al., which use major capitals, e.g., economic, social, and cultural assets, to construct the evaluation system of farm households' livelihood resilience [43,44]. Another is represented by Speranza, which uses buffering capacity, self-organizing capacity and learning capacity to construct the analysis framework of household development resilience [30]. Combining the current situation of the research area and drawing on the studies of Champlin et al., Qamar, Zheng, and Huang [45–47], this study constructed a three-dimensional model of family development resilience encompassing economic resilience. This study assesses household development resilience across three dimensions: economic, social, and cultural. Economic resilience is measured by the expansion of employment opportunities, the diversification of income sources, and the capacity to withstand risks. Social resilience depends on the establishment of social networks, the utilization of social information, and confidence in social governance. Cultural resilience relies on the ability to challenge traditional thinking and adapt to changing environments. Table 1 represents detailed indicators, questions, and assignments. The entropy value method estimates the eight coefficients for each dimension, ultimately yielding the final household development resilience index. The entropy value method, as a multi-criteria decision-making method has the advantage of objective empowerment. It obtains comprehensive evaluation results by calculating the information entropy and weight of each index in the evaluation index system while avoiding the bias brought by subjective factors to a certain extent. It truly reflects the importance of each index in the comprehensive evaluation system, according to Frenken et al. [93].

Table 1. System of indicators for evaluating farm household development resilience.

First Level Indicator (Weight)	Second-Level Index (Weight)	Third-Level Indicator (Weight)	Mean	SD
Economic resilience (0.418)	Ability to expand employment channels (0.198)	It is easy for households to find new job opportunities: strongly disagree = 1; somewhat disagree = 2; generally = 3; somewhat agree = 4; strongly agree = 5	2.749	1.326
	Income source tapping capacity (0.137)	My household has a strong ability to earn money: strongly disagree = 1; somewhat disagree = 2; generally = 3; somewhat agree = 4; strongly agree = 5	2.790	1.392
	Household Risk Resilience (0.083)	Number of social networks that can provide resources for borrowing/one	11.976	5.503
Social resilience (0.332)	Social network conclusion ability (0.084)	Number of supports available to the household when experiencing financial difficulties/one	9.090	4.081
	Social information utilization capacity (0.122)	When faced with new challenges, my household is able to identify viable solutions by utilizing available resources: strongly disagree = 1; somewhat disagree = 2; generally = 3; somewhat agree = 4; strongly agree = 5	2.950	1.349
	Social governance trust capacity (0.126)	I think most people can be trusted: strongly disagree = 1; somewhat disagree = 2; generally = 3; somewhat agree = 4; strongly agree = 5	2.959	1.362

Table 1. Cont.

First Level Indicator (Weight)	Second-Level Index (Weight)	Third-Level Indicator (Weight)	Mean	SD
Cultural resilience (0.250)	Backward thinking breaking ability (0.126)	I am receptive to new things and ideas: strongly disagree = 1; somewhat disagree = 2; generally = 3; somewhat agree = 4; strongly agree = 5	2.924	1.357
	Environmental change learning ability (0.124)	I am able to fully recognize changes and trends in the environment in which I live, and can strengthen my ability to learn and practice in my daily work: strongly disagree = 1; somewhat disagree = 2; generally = 3; somewhat agree = 4; strongly agree = 5	2.902	1.346

Note: SD is the standard deviation.

3.2.2. Independent Variable: Participation in E-Commerce

The mean value for farmers’ participation in e-commerce is 0.3385, indicating that 33.85% of farmers sell their agricultural products through e-commerce channels. Table 1 indicates farmers who do and do not participate in e-commerce with 1 and 0, respectively, including the mean value of participation in e-commerce.

3.2.3. Control Variables

Following economic theory and related literature on factors influencing farmers’ participation in e-commerce and the resilience of family development [29,94–97], this study selects a total of 11 variables across three categories—individual characteristics of the household head, family characteristics, and external environment—that significantly impact farmers’ participation in e-commerce and family development resilience. These variables include gender, age, education level, health status, population size, population burden ratio, business scale, cooperative membership, technical training, cadre status, and distance from the village to the county town. Moreover, the model includes province-dummy variables to consider regional differences. Table 2 provides definitions, assignments, and descriptive statistics for each variable type.

Table 2. Variable definitions, assignments, and descriptive statistics.

Variable Type	Variable	Variable Definition	Mean	SD
Dependent variable	Household development resilience	Calculated by the entropy method	0.081	0.011
	Economic resilience	Calculated by the entropy method	0.034	0.006
	Social resilience	Calculated by the entropy method	0.027	0.004
	Cultural resilience	Calculated by the entropy method	0.020	0.004
Dependent variable	Participation in e-commerce	Whether farmers participate in e-commerce: yes = 1; no = 0	0.339	0.473
Control variable	Sex	Male = 1; Female = 0	0.880	0.325
	Age	Age of head of household (years)	55.636	10.033
	Education	Education of the household head (years)	5.627	1.653
	Health	Health status of household head: very unhealthy = 1; relatively unhealthy = 2; average = 3; relatively healthy = 4; very healthy = 5	3.724	1.092
	Population size	Number of household members (persons)	4.649	1.647
	Population Burden	Percentage of elderly and children among household members	0.358	0.248
	Business Scale	Area of family-run arable land (mu)	9.105	6.758
	Cooperative members	Whether to join farmers’ cooperatives: Yes = 1; No = 0	0.235	0.424
	Technical Training	Number of times participating in agricultural technology training in the recent year (times)	3.034	1.145
	Cadre status	Whether they are village cadres: Yes = 1; No = 0	0.059	0.235
	Township distance	Distance of the village from the county town (km)	4.252	2.504
Province	Shandong Province = 1; Shaanxi Province = 0	0.579	0.494	

Note: SD is the standard deviation.

3.3. Methods

The inclusion or exclusion of farmers in the sample is not random, since their participation in e-commerce is a voluntary decision. This gives rise to a ‘self-selection’ problem that needs to be addressed [21]. To explore the impact of participation in e-commerce on the resilience of farmers’ household development, we employ the PSM method. PSM effectively addresses self-selection bias by constructing a counterfactual hypothesis and matching farmers who participate in e-commerce with those who do not [98,99]. This study matched the treatment group (farmers participating in e-commerce) with the control group (farmers not participating in e-commerce) to analyze the impact of participation in e-commerce on farmers’ household development resilience while controlling for constant external conditions. The analysis proceeds as follows:

First, the Logit model estimates the conditional probability fit value of farmers’ participation in e-commerce, which is expressed through the propensity score value.

$$PS = Pr(C_i = 1 | X) = E(C_i = 0 | X)$$

where PS is the propensity score value, i denotes the i th farmer, X denotes the observable individual characteristics of the household head, family characteristics, and external environment characteristics, and C_i is a dummy variable. If farmers participate in e-commerce, $C_i = 1$; otherwise, $C_i = 0$.

After estimating the conditional probability fit value of farmers’ participation in e-commerce using the Logit model, the treatment group was matched with the control group to explore the impact of e-commerce participation on farmers’ household development. Since different matching methods may cause the empirical results to show differences, but the size of the differences can reflect the degree of robustness of the empirical results, this study employed four matching methods: K-nearest neighbor matching (1 to 1), K-nearest neighbor matching (1 to 4), kernel matching, and caliper matching [100]. Moreover, two tests were conducted: the common support domain test, which examined the overlap range of propensity scores between the treatment and control groups, and the balance test, which evaluated the quality of matching by comparing significant differences between explanatory variables in the two groups.

The basic idea of the PSM model is to find the control group (farmers not participating in e-commerce) similar to the treatment group (farmers participating in e-commerce) according to the model setup, use the data of the control group to simulate the “counterfactual situation” of the experimental group of farmers not participating in e-commerce, and obtain the “family development resilience” effect of the participation in e-commerce of the farmers by comparing the data of the two groups, which is the Average Treatment Effect (ATT) in the model.

$$ATT = E(Y_{1i} | C_i = 1) - E(Y_{0i} | C_i = 1) = E(Y_{1i} - Y_{0i} | C_i = 1)$$

where Y_{1i} signifies the household developmental resilience of farmers participating in e-commerce; Y_{0i} denotes the household developmental resilience in the absence of e-commerce, assuming a scenario where they do not participate in e-commerce. The ATT is the difference in household development resilience between participation in e-commerce and non-participation in e-commerce, i.e., the effect of household development resilience generated by participation in e-commerce only. However, $E(Y_{0i} | C_i = 1)$ is not available due to the fact that the farmer is in fact involved in e-commerce and Y_{0i} does not exist in the real sample. Therefore, farmers close to the propensity score value were sought from the sample not involved in e-commerce. Finally, based on the results of the previous matching, the average treatment effect of farmers’ participation in farmland transfer is calculated.

4. Results

4.1. Logit Model on Determinants of Participation in E-Commerce

Achieving sample matching between e-commerce and non-e-commerce farmers requires regressing the fitted values of conditional probabilities for farmers' participation in e-commerce. Table 3 presents the estimation results of the Logit model. Analyzing individual characteristics shows the negative effect of the age of the household's head on farmers' e-commerce participation, which is statistically significant at the 1% level. This result implies that younger heads of household are more inclined to participate in e-commerce. Furthermore, the number of years of education and the health condition of the household's head exhibit positive effects on e-commerce participation, which are statistically significant at 5% and 10% levels, respectively. This result indicates that higher levels of education and improved health conditions in the household's head lead to a greater inclination towards e-commerce participation. Considering household characteristics, we find that population size, business scale, and technical training have positive effects on farmers' e-commerce participation, which are statistically significant at 5%, 1%, and 10% levels, respectively. This estimation suggests that larger household populations, larger business scales, and greater involvement in technical training contribute to a higher likelihood of participating in e-commerce. Furthermore, township distance indicates a negative impact on farmers' e-commerce participation, which is statistically significant at the 5% level. This result signifies that closer proximity to the township leads to a greater tendency for families to engage in e-commerce.

Table 3. Logit model estimation results of farmers' participation in e-commerce.

Variable	Coefficient	Standard Error	Z-Value
Sex	0.567	0.217	2.619
Age	−0.033 ***	0.007	−4.944
Education	0.073 **	0.040	1.848
Health	0.275 *	0.062	4.411
Population size	0.127 **	0.049	2.629
Population burden	−0.850	0.321	−2.650
Business scale	0.034 ***	0.010	3.557
Cooperative members	0.417	0.150	2.787
Technical training	0.190 *	0.0590	3.226
Cadre status	0.975	0.2670	3.659
Township distance	−0.067 **	0.027	−2.465
Province	−0.310	0.130	−2.390
Constant	−1.747	0.607	−2.879
LR chi ² (13)		147.520 ***	
Pseudo R ²		0.094	
N		1229	

Note: ***, **, and * show statistical significance at 1%, 5%, and 10% levels, respectively.

4.2. Matching Quality

Checking the validity of the PSM estimation results requires conducting tests for the common support domain and conditional independence hypotheses [101]. The interval hypothesis stipulates that the propensity scores should have a large common support domain to minimize sample size reduction during the matching process. The common support domain hypothesis test (Figure 1) demonstrates that the propensity scores of the treated and untreated groups exhibit significant overlap, with the majority of observations falling within the common range of values. This result suggests that the matches are of high quality and satisfy the common support domain hypothesis.

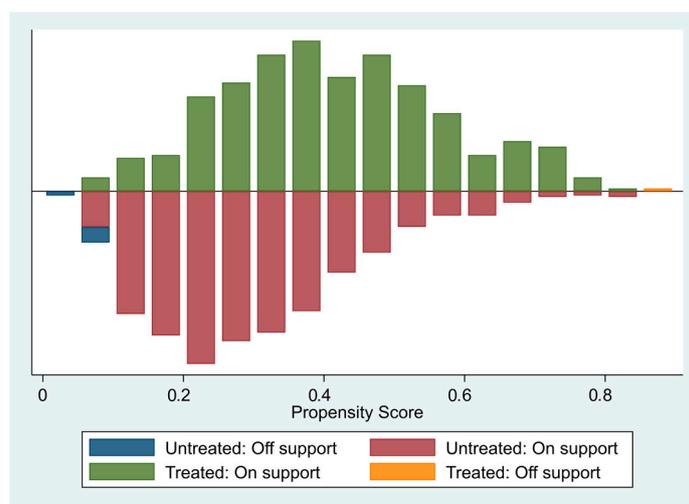


Figure 1. Common support domain assumptions.

Ensuring the reliability of the propensity score results needs a balancing test to reject any systematic differences between the treatment and control groups on each of the matched variables. Table 4 presents the results, demonstrating that the overall Pseudo R^2 of the model decreased from 0.094 before matching to approximately 0.003 after matching, indicating that the matching process has minimized the differences between the two groups. According to the results of the joint significance test of the explanatory variables, the coefficients are statistically significant before matching but insignificant after matching. Furthermore, the mean and median of the covariate deviations both decreased after matching. These findings indicate that the PSM model meets the conditional independence assumption, effectively reducing the differences in the distribution of explanatory variables between the control and treatment groups and eliminating the estimation bias caused by sample self-selection.

Table 4. Results of the explanatory variables balance test before and after matching using PSM.

Sample	Pseudo R^2	LR χ^2	p -Value	Mean Bias	Median Bias	B	R
Unmatched	0.094	147.35	0.000	21.6	21.8	75.9	0.93
Matched	0.003	2.88	0.996	3.0	2.8	11.8	1.01

4.3. Average Treatment Effect of the Participation Impact in E-Commerce on the Household Development Resilience

Table 5 presents the average treatment effects of e-commerce participation on the farm households’ developmental resilience, assessed using four different matching methods. After the application of PSM to account for variations in observable variables, the results show that the impact effect methodology remains consistent with the overall trend, despite disparities in results across the different matching methods. The estimation results from all five matching methods align with each other, and the ATT demonstrates statistical significance at 1% level. Upon averaging the outcomes of the various matching methods, the resulting ATT for household developmental resilience is 0.772, indicating a 9.63% increase for participating e-commerce farmers compared to their non-participating counterparts. This result verifies Hypothesis 1.

Table 5. ATT of the participation impact of e-commerce on household development resilience.

Variable	Matching Method	Treatment Group Mean	Control Group Mean	ATT	t-Stat.	Change Rate (%)
Household development resilience	K-nearest neighbor matching (1 to 1)	8.784	7.997	0.787 ***	8.77	9.84
	K-nearest neighbor matching (1 to 4)	8.784	7.997	0.787 ***	11.02	9.83
	Kernel matching	8.782	8.036	0.746 ***	8.33	9.28
	Caliper matching	8.784	8.016	0.768 ***	11.95	9.57
	Mean	8.783	8.012	0.772 ***	-	9.63
Economic resilience	K-nearest neighbor matching (1 to 1)	3.666	3.348	0.318 ***	6.56	9.51
	K-nearest neighbor matching (1 to 4)	3.666	3.358	0.308 ***	7.59	9.17
	Kernel matching	3.666	3.356	0.310 ***	6.16	9.22
	Caliper matching	3.666	3.355	0.311 ***	8.40	9.26
	Mean	3.666	2.605	1.062 ***	-	9.29
Social resilience	K-nearest neighbor matching (1 to 1)	2.923	2.650	0.273 ***	7.35	10.29
	K-nearest neighbor matching (1 to 4)	2.923	2.644	0.279 ***	9.57	10.54
	Kernel matching	2.921	2.693	0.228 ***	6.33	8.47
	Caliper matching	2.923	2.655	0.268 ***	10.33	10.1
	Mean	2.923	2.661	0.262 ***	-	9.84
Cultural resilience	K-nearest neighbor matching (1 to 1)	2.195	1.999	0.196 ***	6.01	9.8
	K-nearest neighbor matching (1 to 4)	2.195	1.995	0.200 ***	7.72	10.03
	Kernel matching	2.195	1.987	0.208 ***	6.50	10.47
	Caliper matching	2.195	2.006	0.189 ***	8.05	9.4
	Mean	2.195	1.997	0.198 ***	-	9.92

Note: *** show statistical significance at 1% level.

Breaking down the sub-dimensions, the mean treatment effect on economic resilience is 1.062, signifying a 9.29% growth for participating e-commerce farmers compared to their non-participating peers, which accepts Hypothesis 1a. Similarly, the mean treatment effect on social resilience is 0.262, representing a 9.84% increase, confirming Hypothesis 1b. While the mean treatment effect on cultural resilience is 0.198, reflecting a 9.92% growth, which supports Hypothesis 1c. In summary, e-commerce participation significantly enhances the economic, social, and cultural resilience of farmers. Furthermore, cultural resilience has the greatest ATT size before social resilience and economic resilience, with the second and third largest ATT sizes, respectively, in terms of impact magnitude.

4.4. Sensitivity Analysis of the Estimation Results of the PSM Model

The PSM method focuses on sample selection bias resulting from unobservable variables, while ignoring a hidden bias. To assess the significance of any unobservable variables, this study employs the bounds method suggested by Rosenbaum and Rubin (1983) for sensitivity analysis [102]. This method uses the gamma coefficient (Γ) to represent the impact of confounding variables on farm household developmental resilience and its sub-dimensions. The sensitivity analysis examines at what point the conclusions become insignificant as the gamma coefficient increases. If the findings are already insignificant with a gamma coefficient close to 1, then the conclusions are unreliable. On the other hand, if the conclusions remain significant only when the gamma coefficient takes a large value, they can be considered reliable.

Table 6 presents results for the combined effects of multiple PSM methods on the developmental resilience of farm households. The conclusions do not become insignificant

until the gamma coefficient (Γ) is close to 2.7 at the 5% statistical significance level. Economic resilience remains significant at the 5% statistical significance level until the gamma coefficient (Γ) is close to 2.0. Similarly, social resilience remains significant at the 5% level until the gamma coefficient (Γ) is close to 2.1, while cultural resilience remains significant until the gamma coefficient (Γ) is close to 2.0. Therefore, the treatment effect estimates are only slightly sensitive to unobservable variables, reducing concerns that uncontrolled variables may have led to substantial bias in the previous PSM measure.

Table 6. Sensitivity analysis of PSM model estimation results.

Matching Method	Household Development Resilience	Economic Resilience	Social Resilience	Cultural Resilience
K-nearest neighbor matching (1 to 1)	(3.2, 0.078)	(2.2, 0.069)	(2.4, 0.065)	(2.0, 0.078)
K-nearest neighbor matching (1 to 4)	(4.7, 0.055)	(2.7, 0.059)	(3.6, 0.060)	(2.7, 0.056)
Kernel matching	(2.7, 0.067)	(2.0, 0.065)	(2.1, 0.090)	(2.3, 0.074)
Caliper matching	(5.4, 0.059)	(2.9, 0.054)	(4.2, 0.058)	(2.9, 0.054)

4.5. Mechanism Analysis

According to the previous analysis, participating in e-commerce significantly contributes to the development resilience of farm households. However, further investigation is needed to understand how participation in e-commerce specifically affects the development resilience of these households. As mentioned earlier, participation in e-commerce impacts farm households’ development resilience through three primary mechanisms. First, it facilitates economic benefits by helping farmers search for employment opportunities and improve agricultural income. This economic foundation supports the enhancement of development resilience, which is measured in this study using the logarithm of annual farming household income. Secondly, participation in e-commerce expands the social network of farm households, thereby strengthening their development resilience. The level of agreement with the statement ‘your family’s social network is wider’ is used as an indicator, categorized from strongly disagree (1) to strongly agree (5). Thirdly, participation in e-commerce effectively increases farmers’ risk appetite, influencing the resilience of their household development. To measure risk appetite, we categorize farmers into three levels: weak risk appetite (1), average risk appetite (2), and strong risk appetite (3). This paper utilizes stepwise regression to examine the role of these three mechanism variables in the relationship between participation in e-commerce and the resilience of farm household development. Table 7 represents the results of the mechanism test, assessing the impact of e-commerce participation on the developmental resilience of farm households.

Table 7. Mechanism test results.

	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Household Development Resilience	Economic Gains	Household Development Resilience	Network Ties	Household Development Resilience	Risk Appetite	Household Development Resilience
Participation in e-commerce	0.770 *** (0.058)	4.387 *** (0.334)	0.715 *** (0.062)	1.435 *** (0.068)	0.417 *** (0.065)	0.651 *** (0.047)	0.460 *** (0.057)
Economic gains			0.013 ** (0.005)				
Network ties					0.246 *** (0.023)		
Risk appetite							0.476 *** (0.032)
Constant	7.486 *** (0.239)	9.522 *** (1.381)	7.367 *** (0.243)	1.749 *** (0.281)	7.056 *** (0.232)	1.336 *** (0.195)	6.849 *** (0.224)
N	1229	1229	1229	1229	1229	1229	1229
Adj R ²	0.272	0.212	0.275	0.329	0.332	0.198	0.381

Note: *** and ** show statistical significance at 1% and 5% levels, respectively.

Table 7 shows the results of the mechanism tests. According to the results of model (1), the coefficient of participation in e-commerce is 0.770, which is statistically significant at 1% level, implying its positive and considerable effect on the developmental resilience of farm households. Based on the results of model (2), participation in e-commerce has a positive and significant effect on the economic benefits of farm households, suggesting a substantial increase in their economic benefits. The regression coefficients for participation in e-commerce and economic interests in model (3) are statistically significant, confirming the mediating effect of economic interests on the relationship between participation in e-commerce and the resilience of farm household development and accepting Hypothesis 2. Regarding the results of model (4), the coefficient of participation in e-commerce is 1.435, which is positive and statistically significant at the 1% level, revealing its positive and considerable effect on the network relationships of farm households and signifying an expansion of their social network. The regression coefficients for participation in e-commerce and network relationship linkage are statistically significant at the 1% level in model (5), affirming the mediating effect of network relationship linkage in the connection of e-commerce participation with the development resilience of farm households and accepting Hypothesis 3. Finally, the results of model (6) demonstrate that the coefficient of commerce participation is 0.651, which is positive and statistically significant at the 1% level, indicating its positive and substantial effect on the risk appetite of farm households. The regression coefficients for participation in e-commerce and risk preference in model (7) are statistically significant at 1% level, accepting the mediating role of risk preference in the relationship between e-commerce participation and the resilience of farm household development and accepting Hypothesis 4.

4.6. Heterogeneous Effects

4.6.1. Heterogeneous Effects of Education

The regression results in Table 8 (1) reveal that even after incorporating the interaction term between e-commerce participation and years of education, the positive effect on the developmental resilience of farm households remains significant at the 10% level. Furthermore, the interaction term itself demonstrates a significant and positive impact on the developmental resilience of farm households at the 10% level. These findings suggest that the positive contribution of e-commerce participation to the developmental resilience of farm households is associated with the duration of education. In other words, farmers with higher levels of education are more likely to discover greater development opportunities through participating in e-commerce compared to those with shorter educational backgrounds. This indicates heterogeneity in the impact of e-commerce participation on the resilience of farmers’ households based on their educational attainment.

Table 8. Estimated results of heterogeneity analysis.

	(1) Household Development Resilience	(2) Household Development Resilience	(3) Household Development Resilience
Participation in e-commerce	0.416 * (0.215)	0.840 *** (0.066)	
Participation in e-commerce × Education	0.062 * (0.036)		
Participation in e-commerce × Cooperatives Members		−0.265 ** (0.125)	
Live streaming with goods			1.249 *** (0.120)
Platform e-commerce			0.872 *** (0.127)
Social e-commerce			0.666 *** (0.068)
Locally self-built platforms			0.610 *** (0.131)
Constant	7.567 *** (0.243)	7.486 *** (0.238)	7.469 *** (0.237)
N	1229	1229	1229
Adj R ²	0.273	0.274	0.284

Note: ***, **, and * show statistical significance at 1%, 5%, and 10% levels, respectively.

4.6.2. Heterogeneous Effects of Organizational Participation

The regression results in Table 8 indicate that even after introducing the interaction term between participation in e-commerce and cooperative membership, the positive effect of e-commerce participation on farmers' household development resilience remains significant at 1% level. Moreover, the interaction term itself shows a significant and negative impact on farmers' household development resilience at the 5% level. These findings imply that e-commerce participation has a greater positive effect on the development resilience of farmers' households who are members of cooperatives compared to those who are not. Furthermore, there is heterogeneity in organizational participation regarding the impact of e-commerce participation on the resilience of farmers' households.

4.6.3. Heterogeneous Effects of E-Commerce Participation Types

Actually, farmers engaged in e-commerce employ various methods. This study categorizes e-commerce participation into live streaming with goods, platform e-commerce, social e-commerce, and locally self-built platforms, considering farmers' actual involvement. The estimation results in column (3) of Table 8 reveal the coefficients indicating the impact of these different types of e-commerce on farmers' household development resilience compared to non-participating farmers. Specifically, the coefficients for live streaming with goods, platform e-commerce, social e-commerce, and locally self-built platforms are 1.249, 0.872, 0.666, and 0.610, respectively. These findings suggest that live streaming with goods has the greatest positive effect on farmers' household development resilience, followed by platform e-commerce and social e-commerce. Conversely, local self-built platforms play a relatively minor role in promoting the resilience of farmers' households. This discrepancy can be attributed to the superior sales and earnings of farmers engaged in live streaming of goods and platform e-commerce, providing a stronger economic foundation for household resilience. Although local self-built platforms also contribute to enhancing farm household resilience, their effectiveness relies on local government support, resulting in a comparatively weaker influence.

5. Discussion

This study investigates the impact, mechanism, and heterogeneity of rural e-commerce participation on the developmental resilience of farmer households using micro-level data from Shaanxi and Shandong provinces in China. The findings indicate that engagement in rural e-commerce enhances the developmental resilience of farmer households. Furthermore, participation in rural e-commerce primarily influences the developmental resilience of farmer households through three mechanisms: improving economic efficiency, establishing network linkages, and shaping risk preferences. The findings of this study reveal that participation in e-commerce has an important role in household development resilience. This finding is consistent with the results of previous studies by Wei et al. (2024) and Lin et al. (2024), which similarly proved the important role of participation in e-commerce in affecting the economic, social, and cultural aspects of household development for farmers [52,103]. Participation in e-commerce, as a new means of selling agricultural products, effectively improves the quantity and quality of agricultural products sold and provides farmers with more income-generating opportunities and employment and entrepreneurship opportunities, thus effectively improving the farmers' economic resilience to risk [58]. Household development resilience mainly reflects the household's ability to resist, adapt and transform in the face of risky shocks [104]. Existing studies have emphasized the impact of various factors on household economic resilience. Internal factors such as the household's demographic structure, health status, and level of education, as well as external factors such as natural disasters, political systems, and social conflicts, all have an impact on the household's development resilience [105,106]. This study shows that participation in e-commerce enhances household economic, political, and cultural resilience. Therefore, the government should increase its efforts to promote participation in e-commerce.

Secondly, the results of this study indicate that participation in e-commerce affects household development resilience through improving economic efficiency, network relationship linkage, and risk appetite, all of which contribute significantly to the enhancement of household development resilience. First, participation in e-commerce can affect household development resilience by improving economic efficiency. One reason is that participation in e-commerce can promote effective docking between farmers and the consumer market, saving transaction costs and lowering the threshold for farmers to sell their agricultural products, which in turn raises the farmers' income level [107,108]. Another reason is that participation in e-commerce promotes the non-farm employment of farm households, which promotes the income level of farm households [109]. Farm household income is an important embodiment of household development resilience, and the increase in farm household income effectively enhances household development resilience. In addition, participation in e-commerce can have a positive impact on household development resilience through its network relationship linkage. One explanation is that e-commerce promotes stronger communication between producers and consumers to improve efficiency and branding. Stronger communication, in turn, can help promote the expansion of the social circle among farmers, thus promoting the breadth of their social network relationships [110]. Another explanation is that Internet channels such as e-commerce platforms can reduce the cost of accumulating and maintaining social networks for farmers. This improves the maintenance of their existing external relationships, the establishment of new social connections, and the close social network relationships between farm families, thus deepening the social network relationships of farmers [111]. The construction of social networks helps e-commerce entrepreneurs accumulate human capital, enhancing the ability of farmers to cope with risks, thus improving household development resilience [112]. Finally, participation in e-commerce can have a positive impact on household development resilience through risk appetite. Participation in e-commerce can reduce the risk of stagnation of agricultural products and change the risk appetite of farm households. Risk appetite households tend to make "aggressive" production decisions aimed at increasing labor productivity and stimulating growth in farm income and output, thereby reducing household vulnerability [113].

However, the proportion of Chinese farmers participating in e-commerce is still low due to the influence of factors such as the small scale of operations and decentralization of business entities, and the impact on household development resilience has not achieved the expected results. This thesis not only studies the effect of participation in e-commerce on household development resilience but also explores the influencing factors of participation in e-commerce. However, several aspects of this study differ from previous studies. Notably, this study reveals that cooperative members do not work on participation in e-commerce, which is inconsistent with the study of Chen C. et al. [85]. The main reason for this difference is that with the development of e-commerce, the threshold for farmers to participate in e-commerce has been gradually lowered, and cooperatives are no longer a required factor. In addition, cadre status does not play a role in participating in e-commerce, while Yue Z. et al. showed that cadre status promotes farmers' participation in e-commerce [114]. The main reason for this difference is that cadre status farmers are generally older, assess a stronger sense of risk avoidance, and have weaker incentives to participate in e-commerce [115].

Despite some basic conclusions, this study has some limitations. First, due to the limitations of the survey area, there may be regional applicability issues with the results of the study. Future studies should expand the scope of the study to include more farmers of different agricultural varieties and agro-industrial zones, thereby increasing the general applicability of the results. Secondly, the questionnaire used in this study was mainly self-reported by farmers, and self-reported e-commerce participation behavior is usually overestimated due to the different interpretations of the questionnaire by the respondents during the study. Therefore, future studies should consider counseling respondents and farmers on the questionnaire prior to the study in order to reduce the potential bias caused by self-reported behavior. Finally, household development resilience is a dynamic process

of change. The data used in this study were cross-sectional data from the same year, making it difficult to dynamically observe changes in farmers' behavior over time.

6. Conclusions and Policy Recommendations

This paper conducts an in-depth analysis regarding the impact of e-commerce participation on the developmental resilience of farm households and explores its underlying mechanisms using data from 1229 apple farmers' micro-surveys conducted in Shandong and Shaanxi provinces. The results indicate that e-commerce participation has a significant and positive impact on the developmental resilience of farm households. Specifically, participating farm households show greater resilience to household development than those not involved in e-commerce. Further analysis reveals that e-commerce participation enhances the economic efficiency of farm households, promotes network relationship linkage, provides interpersonal support for development, and improves the risk-resistant capacity of farm households, ultimately enhancing their developmental resilience. Heterogeneity analysis indicates that the impact of e-commerce participation on the developmental resilience of farmers varies based on their endowment constraints. In general, it has a greater effect on enhancing those with higher levels of education, younger age, more technical training, and non-membership in cooperatives.

This paper yields the following policy insights based on the research findings: Firstly, the government should continue fostering the development of rural e-commerce and encourage more farmers to participate in e-commerce activities. Additionally, optimizing the business environment in rural areas and promoting the mutual development of rural e-commerce and agricultural production can enhance the economic, social, and cultural resilience of farmers. Rural e-commerce has transformed the lifestyle and production of farmers, and promoting its development can enrich the living and production environments of farmers, thereby enhancing the resilience of farming households. Secondly, implementing differentiated policy measures and incentive tools based on the endowment characteristics of farm households can encourage farmers with higher endowment characteristics to participate in rural e-commerce. This, in turn, can guide more farmers to join e-commerce activities by passing on help, thereby enhancing the overall resilience of regional family development. Finally, increasing technical training can reduce the threshold for farmers' participation in e-commerce. Given that some farmers face technological and age-related constraints that prevent them from rural e-commerce benefits, the government should provide more technical training and practical operations to help farmers overcome these obstacles.

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