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Exploring the Income-Increasing Benefits of Rural E-Commerce in China: Implications for the Sustainable Development of Farmers

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Abstract: The slowdown in income not only hinders the sustainable development of farmers but also exacerbates ecological and environmental problems. Likewise, the digital economy model represented by e-commerce has become a key path for growing farmers' income. This article is based on 2020 China Rural Revitalization Survey data and uses the OLS and mediation effect models to examine the impact and mechanism of e-commerce operations on farmers' income. The research results indicate that e-commerce operations can significantly improve the income level of farmers. After robustness and endogeneity tests, this conclusion still holds. The mechanism analysis results indicate that e-commerce operations promote farmers' income growth by enhancing information acquisition, reducing operating costs, and enhancing financial support. The results of the heterogeneity analysis indicate that the impact of e-commerce on farmers' income is heterogeneous in terms of income structure, education level, and regional distribution. Specifically, e-commerce significantly increases farmers' agricultural operating income, non-agricultural operating income, and transfer income but significantly reduces their wage income. At the same time, e-commerce has a more significant income-increasing effect on highly educated and central and western farmers. Therefore, in promoting the development of a rural digital economy, it is necessary to improve the supporting facilities of e-commerce in rural areas; strengthen the supply of information, technology, capital, talent, and other elements; continue to improve the inclusiveness of rural e-commerce; and promote the sustainable growth of farmers' income. The above findings not only provide new channels and ideas for farmers to increase income through e-commerce operations, but also help relevant decision-making departments to formulate new policies to promote farmers' income growth and the development of e-commerce in China.

Keywords: digital economy; rural e-commerce; farmer income; sustainability of farmers

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1. Introduction

A decrease in income can lead to various problems, such as deteriorating health conditions, social stratification, and a deteriorating ecological environment, which are not conducive to achieving sustainable development goals. In 2020, China completed the task of eradicating absolute poverty and building a moderately prosperous society in all aspects. Rural residents' per capita disposable income also showed a growing trend [1], and the relative income gap between them and urban residents shrunk significantly. However, structural contradictions in the growth of the income of rural residents were prominent, the growth rate gradually was steadily declining, and the absolute income gap between urban and rural residents kept growing [2,3], rising from CNY 12,506.7 in 2010 to CNY 28,481 in 2021, with an average annual expansion of CNY 1452.2. Meanwhile, there is an increasing disparity in rural residents' incomes across regions [4]. One of the main sources

of income inequality is the absolute income gap between urban and rural residents, as well as the income gap within rural areas [5], which is detrimental to the high-quality development of the economy and social harmony and stability. Rural residents urgently need to create varied and stable income-generating channels in order to assure sustained and steady income growth, given the worsening global economic conditions and mounting pressure from the economic slump.

Facing the goal of a common prosperity vision, ensuring faster income growth for most rural households is the key to achieving common prosperity for all [6]. The growth of rural household income is mainly affected by the dual impact of policy and market, which act and intertwine with each other, forming a complex relationship structure. For example, the government has implemented regional poverty alleviation policies, industrial policies, and pilot policies encouraging people to return home to start businesses. These promote employment for residents, support agricultural production, improve population quality, and enhance the production and living environment, thereby achieving the goal of increasing farmers' income [7]. Various fiscal policies to support agriculture, such as agricultural expenditure policies and infrastructure construction expenditure policies, have promoted the income growth of rural households [8], while this income-generating effect is differentiated in terms of region, topography, and stage of economic development, and social security expenditure policies have helped to narrow the intra-rural income gap [9]. On the other hand, market reforms provide a power source for rural household income growth [10]. The further improvement in the rural arable land transfer market and the agricultural social service market enables farmers to effectively allocate production factors and achieve household income growth [11]. Through the factor endowment effect, infrastructure supporting effect, production efficiency effect, and product competition effect, the structural reform of the agricultural supply side enhances the autonomous management ability of farmers; promotes the integrated development of rural primary, secondary, and tertiary industries; builds modern agricultural industrial, production, and management systems; and achieves an increase in rural household income.

In the era of the digital economy, e-commerce, based on modern information technology, has become one of the most important means to stimulate the growth of rural residents' income by organically connecting rural residents with modern markets [12–14]. It has been shown that e-commerce can create a sustainable value chain for the local area, promote information flow and industry coordination, enhance market transparency, optimize resource allocation, and increase rural household income [15–17]. E-commerce provides a reliable path for growing farmers' income by increasing the added value and potential returns of agricultural products and shifting farmers from obtaining producer prices to obtaining consumer prices while selling their products [18]. E-commerce helps to drive the development of supporting industries such as production, processing, warehousing, and logistics; promotes the transformation and upgrading of supporting industries; accelerates the revitalization of rural industries [18]; and supports a sustained increase in farmers' income. E-commerce is an important channel for farmers in developing countries to share the dividends of economic development by adjusting the industrial structure, increasing non-farming employment opportunities [19–22] and promoting an increase in rural households' wage income. From the perspective of circulation, e-commerce empowers small farmers to directly connect with consumers, significantly reduces intermediate links, promotes the sharing of digital dividends by traditionally disadvantaged groups [18,23], alters the disadvantaged position of farmers in the industrial chain and market structure, and strengthens the counter-cyclicality of agricultural products while reducing the cost of transaction regulation, effectively reducing the risk of product stagnation and increasing farmers' income [24]. Currently, China's rural economy is in the stage of rapid transformation, and digital technology and its derivatives have become an important force in promoting farmers' income [25].

In general, scholars generally recognize that e-commerce can drive rural economic development and increase the income of rural households, which provides a good foundation

for this study. However, there is still room for further expansion. First, the content of the existing research mainly stems from a single path to examine the impact of e-commerce operations on farmers' income and may ignore the impact of other paths. It is difficult to identify the income-generating effects of the e-commerce operations of farmers and income-generating paths; there is a need to clarify the mechanism from several aspects and examine the endowment of different farmers and regions regarding the need for e-commerce operations. This can be achieved by studying the heterogeneity of the effect of income-generation analysis. Secondly, regarding the research region, the existing research mainly focuses on the development of e-commerce at the regional level, the survey sample coverage is limited, the representativeness and robustness of the research conclusions are affected, and the external validity of the proposed policy is relatively insufficient. Thirdly, regarding the research perspective, the existing research mainly uses macro-data or industry data to explore the income-generating effect of e-commerce, which may indicate the fallacy of composition. Based on this, this study uses data from the 2020 China Rural Revitalization Survey (CRRS) "URL (http://rdi.cssn.cn/ggl/202210/t20221024_5551642.shtml, accessed on 25 August 2024)", adopts the Ordinary Least Squares (OLS) model and the mediated effect model to explore the impact and mechanism of e-commerce operation on the income of rural households, and further examines the heterogeneous impact of e-commerce operation on the income of rural households in order to provide new micro-evidence for a comprehensive examination of the income-raising effects of e-commerce and policy references for broadening the income-generating channels of rural households.

2. Theoretical Analysis and Research Hypotheses

2.1. The Impact of E-Commerce Operations on Farmers' Income

E-commerce operations have a positive role to play in promoting farmers' income. Rural e-commerce has gradually extended from the distribution end to the upstream links of the industrial chain, such as agricultural production and agricultural product processing, to promote the comprehensive digital upgrading of agriculture in the supply of means of production, socialized service guarantee, product processing, circulation and storage, brand marketing, after-sales service, etc., so as to promote the growth of the income of rural households and the development of the rural economy [18,19]. When participating in e-commerce, farmers can obtain more comprehensive market information, which helps them to make rational decisions and accurate market positioning, increase product exposure, and expand the scope of sales with e-commerce platform traffic so as to achieve income growth [26]. The growth in operating income comes from the dividend of connecting agricultural production and consumption [25]. In the traditional production and marketing model, intermediaries separate farmers' production attributes and marketing attributes and divide smallholder interests in controlling commodities, information, and customers [18]. Compared to the traditional industrial chain operation mode of production and marketing separation, rural e-commerce greatly compresses the intermediate links of the traditional "producer–buyer–wholesaler–retailer" mode, enabling farmers and consumers to directly interface, reducing the cost of commodity circulation and helping to stimulate the development of the industry. This reduces the cost of commodity circulation, which is conducive to stimulating consumption growth and thus increasing income from commodity sales. In addition, the low-threshold education and training resources provided by the e-commerce platform can enhance the human capital level of farmers to a certain extent. Its embedded Internet technology can expand social network resources, establish and develop weak social relationships, and promote the farmers' accumulation of social capital, thus stabilizing the supply of agricultural products, increasing the volume of commodity sales, and enhancing the e-commerce operation performance and farmers' income levels [27,28].

Based on the above analysis, research hypothesis H1 of this study is proposed.

H1. *E-commerce operation has a significant positive impact on farmers' income.*

2.2. Mechanisms of the Impact of E-Commerce Operation on Farmers' Income

The essence of e-commerce is a business activity centered on commodity exchange with the help of information network technology [29]. The business scope of e-commerce has expanded from simple commodity transactions to finance, logistics transactions, and other fields. It has transformed from the commodity supply chain to the industrial supply chain, becoming an indispensable part of the digital economy. The development of China's e-commerce extends the digital dividend to rural residents, providing a strong guarantee for the increase in rural household income and rural industrial development (as shown in Figure 1).

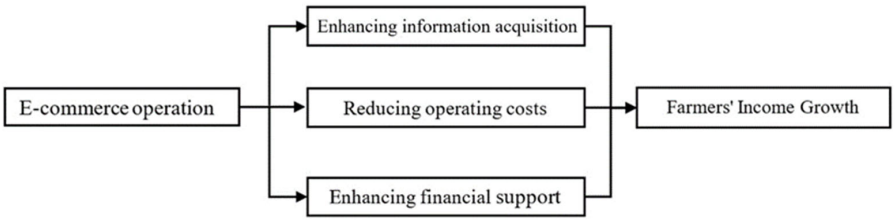


Figure 1. The mechanisms of the impact of e-commerce operations on farmers' incomes.

First, e-commerce operations can strengthen information acquisition and reduce information constraints, thus increasing rural household incomes. E-commerce operations based on Internet applications can significantly enhance the information search, utilization, and transformation capabilities of farmers; avoid decision-making errors caused by asymmetric and incomplete information; reduce production and business risks; and reduce business losses [30–32]. The business environment of traditional agricultural business methods is territorial, market information is scattered, and the lag and distortion of information transmission are serious, which not only hinders the provision of effective guidance to the production and operation of farmers but is also sometimes misleading. E-commerce utilizes the information advantages of Internet technology to break the time and space boundaries of information exchange, making information dissemination faster and more convenient. E-commerce provides small farmers with access to a wider online market [33]; transmits marketing information to consumers faster, benefits producers and consumers in both directions [34]; and further expands the scope of sales, thus increasing the operating income of farmers.

Secondly, e-commerce operations can reduce operating costs and improve operating profits, thus increasing farmers' income. On the one hand, farmers can use the e-commerce platform to compare prices, check the prices of different raw materials, and reduce the procurement costs of production materials and technical services. E-commerce operation expands farmers' access to raw materials, and with the economies of scale and diminishing marginal cost effect [35] embedded in the Internet, it further reduces farmers' operating costs. The traceability system of the e-commerce platform can provide farmers with a good after-sales service, which can avoid counterfeit and shoddy agricultural materials for the production of agricultural products while saving operating costs [25] and reducing cost losses. On the other hand, after farmers are integrated into the e-commerce market, they perform market transaction functions by utilizing information technology, which reduces the spatial and temporal limitations of market transactions and can quickly match supply and demand, improve transaction efficiency, and reduce transaction costs [26], forming a "highly efficient and frictionless" transaction model.

Thirdly, e-commerce can enhance financial support and alleviate financial pressure, thus increasing farmers' income. Farmers cannot forego financial support in production and operation, but the traditional rural financial service model has a high threshold, high cost, limited coverage, and other problems, which makes it difficult to effectively meet the financial needs of farmers. After farmers participate in e-commerce, they can fully use Internet tools to reduce the cost of access to financial services and improve the accessibility of financial services through digital inclusive finance. Digital technology, as an important

carrier for the development of inclusive finance, can accurately locate funds for the most needy rural households while pooling idle urban funds due to its ability to cross the geographical divide. E-commerce operation provides a convenient channel for farmers' financing; promotes a high degree of sharing and integration of cash flow, information flow, and logistics; and can satisfy farmers' demand for diversified financial products, effectively alleviate farmers' credit constraints, and enhance income levels.

Based on the above analysis, research hypothesis H2 of this study is proposed.

H2a. *E-commerce operation increases farmers' income by enhancing information acquisition and support.*

H2b. *E-commerce operation increases farmers' income by reducing operating cost support.*

H2c. *E-commerce operation increases farmers' income by enhancing financial support.*

2.3. Heterogeneous Impact of E-Commerce Operation on Farmers' Income

The income-generating effects of e-commerce operations on rural households differ in income structure. The income structure of rural households usually includes business, property, wage, and transfer income. The e-commerce platform provides a convenient channel for farmers to sell their products (agricultural and non-agricultural products), expanding the scope of sales, and its convenient payment method also reduces the cost of sales, which significantly improves farmers' agricultural operating income and non-agricultural operating income [36]. Meanwhile, the various e-commerce support and subsidy policies introduced by the government have further increased the transfer income of rural households. In addition, rural e-commerce operations are mainly based on rural household units, which crowd out non-farm employment time to a certain extent, thus reducing the wage income of rural households. In contrast, property income mainly comes from asset appreciation, for which the impact of e-commerce operations is not obvious.

The income-generating effect of e-commerce operations on rural households varies in terms of education level. The level of education characterizes the human capital level of rural households to a certain extent. Generally, the more educated a user is, the more they can utilize the Internet to gain income [37]. Given the practice of the Taobao village, the rapid development of e-commerce and the rules of market competition force farmers to obtain a high level of digital literacy, such as the ability to use interconnection, deal with words and pictures, understand product quality management, and gain an awareness of business services and product brands. Rural households with high education levels generally have stronger learning abilities and innovation consciousness. They can better adapt to the fierce e-commerce competition market, improve online sales performance, and increase sales income [38].

The income-generating effect of e-commerce operations on farmers is heterogeneous in its regional distribution. Different levels of economic development between regions create differences in their e-commerce infrastructure construction, and the speed of e-commerce development in the eastern region is significantly higher than in the central and western regions. The Internet, as the infrastructure for e-commerce development, gradually diminishes its marginal effect on economic development as its popularization continues to expand. Compared to the eastern region, the pulling effect of e-commerce operations on farmers' income in the central and western regions is more obvious. Especially for farmers in the poor areas of Central and Western China, the network direct sales model can reduce the dependence on intermediary channels, share more value in the industrial chain, and significantly improve income levels [39].

Based on the above analysis, research hypothesis H3 of this study is proposed.

H3a. *The impact of e-commerce operation on farmers' income is heterogeneous in terms of income structure.*

H3b. *The impact of e-commerce operation on farmers' income is heterogeneous in terms of education level.*

H3c. *The impact of e-commerce operation on farmers' income is heterogeneous in terms of regional distribution.*

3. Data Sources, Variable Selection, and Model Construction

3.1. Data Sources

The data in this study came from the 2020 China Rural Revitalization Survey (CRRS), a comprehensive survey initiated by the Institute of Rural Development of the Chinese Academy of Social Sciences (CASS) in 2020 that covers a wide range of aspects, including agricultural production, rural development, farmers' lives, and social well-being. The CRRS data adopt a combination of stratified and random sampling, which is relatively representative. First of all, the research group considered the level of economic development, regional location, and agricultural development and randomly selected samples from provinces in the East, Central, West, and Northeast regions, including 10 provinces in Guangdong, Zhejiang, Shandong, Anhui, Henan, Guizhou, Sichuan, Shaanxi, Ningxia, and Heilongjiang. Secondly, the research group grouped all counties (cities and districts) into five groups according to the per capita GDP and randomly selected one county (city and district) from each group, considering the geospatial distribution of counties, i.e., five counties (cities and districts) from each sample province. Once again, the research group randomly selected three townships from each county (city and district) and then divided the administrative villages in each township into two groups of "better" and "worse", with one village randomly selected from each group; finally, the researcher adopted the equidistant sampling method and randomly selected one village from the roster of rural households provided by the village committee. Finally, the researcher randomly selected 12–14 farmers from the roster of farmers provided by the village committee using the equidistant sampling method and conducted field research according to the questionnaire.

The data source has several advantages: Firstly, the sample size of the data is very large (more than 3800 farmer survey questionnaires), which has very good representativeness and typicality. Secondly, the data sample coverage is very wide, covering ten provinces (regions) including Guangdong Province, Zhejiang Province, Shandong Province, Anhui Province, Henan Province, Heilongjiang Province, Guizhou Province, Sichuan Province, Shaanxi Province, and Ningxia Hui Autonomous Region, as well as 50 counties (cities) and 156 townships (towns) nationwide, with good representativeness and reliable data regression results. Thirdly, the survey was initiated and completed by the Institute of Rural Development of the Chinese Academy of Social Sciences as a large-scale national rural tracking survey, with a very high level and guaranteed data quality, which is conducive to the reliability of the research results. Fourthly, high-quality data surveys provide a comprehensive and cutting-edge understanding of the development of e-commerce in rural China, which is representative. The fifth point is that there is a positive correlation between rural online sales and per capita disposable income in rural areas, and the contribution pattern of e-commerce operations to farmers' income growth still applies.

This study focused on the relationship between e-commerce operations and farmers' income, and 2783 samples of farmers were selected for the study after removing missing values and outliers.

3.2. Variable Selection

3.2.1. Dependent Variables

Drawing on the study by Kumar and Kumara [30], this study used both the total household income and per capita household income of rural households to measure the income level of rural households. In order to minimize the interference of heteroscedasticity

of income variables, this study used the natural logarithm of total household income and per capita household income to measure the income level of rural households.

3.2.2. Core Independent Variables

The purpose of this study was to examine the impact of e-commerce operations on rural household income. Drawing on the study by Li et al. [14] and combining data availability, e-commerce operation was measured using the indicator of whether or not to sell products in the network. If selling products in the network is regarded as e-commerce operation behavior, it was assigned a value of 1; otherwise, it was regarded as not having e-commerce operation behavior, assigned a value of 0.

3.2.3. Mediating Variables

Based on the previous theoretical analysis, it is known that e-commerce operation increases farmers' income by enhancing information acquisition, reducing operating costs, and enhancing financial support. The indicators of whether farmers can obtain information to meet their needs through the Internet, purchase agricultural materials through online channels, and obtain credit from financial institutions were selected to measure the mediating variables of enhancing information acquisition, reducing operating costs, and enhancing financial support, respectively.

3.2.4. Control Variables

In addition to e-commerce operations, other variables also have an impact on rural household income. Drawing on the study by Li et al. [14], this study selected control variables from the three dimensions of the individual characteristics of rural households, household characteristics, and village characteristics. Individual characteristics includes gender, age, age-squared term, marital status, political profile, health status, education level, and e-commerce training; household characteristics includes the household size, the number of household village cadres, and household cooperative participation; and village characteristics includes the village topography, geographic location, and distance from the county government (Table 1).

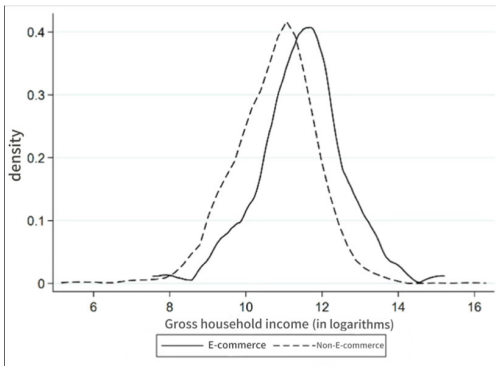
Table 1. Definition of variables and descriptive statistic results.

Variables	Variable Name	Variable Interpretation and Explanation	Mean	Std	Min	Max
Dependent variables	Total household income	The total net income of rural households (CNY), taken as the logarithm	10.812	1.101	5.337	16.12
	Household per capita income	The per capita net income of rural households (CNY), taken as logarithmic	9.451	1.066	3.589	15.427
Core independent variables	E-commerce operation	Whether the farmer sells products online (yes = 1, no = 0)	0.071	0.257	0	1
Mediating variables	Enhance information acquisition	Whether farmers can satisfy themselves through the Internet Information on requests (not at all satisfied = 1, not very satisfied = 2, fair = 3, basically satisfied = 4, fully satisfied = 5)	3.999	1.043	1	5
	Reduce operating costs	Whether farmers purchase agricultural materials through online channels (yes = 1, no = 0)	0.344	0.475	0	1
	Enhance financial support	An indicator of whether the rural household has access to credit from financial institutions (yes = 1, no = 0)	0.509	0.500	0	1

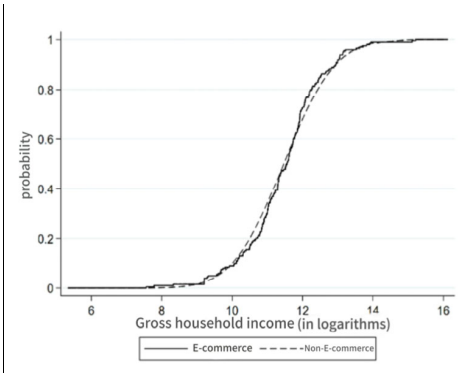
Table 1. *Cont.*

Variables	Variable Name	Variable Interpretation and Explanation	Mean	Std	Min	Max
Control variables	Gender	The sex of the head of the household (male = 1, female = 0)	0.955	0.206	0	1
	Age	The age of the head of the household (years)	55.058	11.470	18	102
	Square term of age	The square of the age of the head of the household divided by 100	31.629	12.495	0.640	104.04
	Marital status	Whether the head of the household is married (yes = 1, no = 0)	0.986	0.119	0	1
	Political affiliations	Whether the head of the household is a member of the CPC (yes = 1, no = 0)	0.244	0.430	0	1
	Health status	The health status of the head of the household (very poor = 1, poor = 2, fair = 3, good = 4, very good = 5)	3.606	1.012	1	5
	Educational attainment	Educational attainment of the head of the household (elementary school and below = 1, junior high school = 2, middle school, high school, vocational high school and technical school = 3, university college = 4, university undergraduate = 5)	1.853	0.759	1	5
	E-commerce training	Whether the household head has received training in e-commerce (yes = 1, no = 0)	0.074	0.261	0	1
	Number of families	Number of household personnel (number)	4.184	1.476	1	10
	Number of family village cadres	The number of village cadres among household members (number)	0.113	0.326	0	3
	Family cooperative participation	Whether any member of the household participates in a cooperative (yes = 1, no = 0)	0.258	0.437	0	1
	Village topography	Plains = 1, hills = 2, semi-mountainous = 3, mountainous = 4	2.225	1.315	1	4
	Geographic location of the village	Whether the village is part of an urban suburb (yes = 1, no = 0)	0.208	0.406	0	1
	Distance of the village from the county government	The distance from the village council to the county government (kilometers)	23.221	16.918	1	125

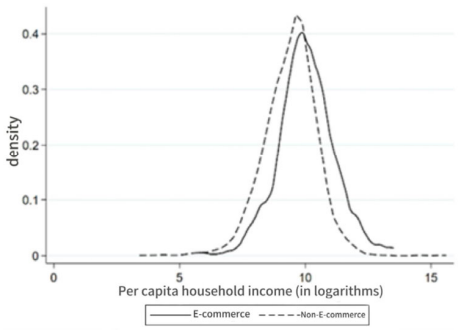
This study compared the incomes of farmers in e-commerce and non-e-commerce operations. Figure 2 shows the density distribution and cumulative distribution of the rural household income. It can be seen in the figure that there are more e-commerce operated rural households in the higher-income rural household samples, while there are more non-e-commerce-operated rural households in the lower-income rural household samples. Thus, it can be preliminarily concluded that e-commerce operation plays an important role in promoting the growth of rural household income. Of course, a more rigorous econometric analysis is still needed to confirm the effect of e-commerce operations on rural household incomes; the following section will aim to empirically achieve this.



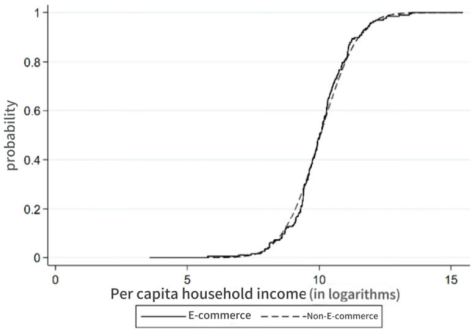
(**a**) The density distribution of total household income.



(**b**) The cumulative distribution of total household income.



(**c**) The density distribution of per capita income.



(**d**) The cumulative distribution of per capita income.

Figure 2. The income density distribution and cumulative distribution of rural households.

3.3. Model Construction

3.3.1. Benchmark Regression Model

Considering that the dependent variable in this study, i.e., rural household income, is a continuous variable, an OLS model was constructed for empirical testing.

$$Yi = \alpha + \beta Eci + \lambda Xi + \varepsilon i \quad (1)$$

In Equation (1), Yi indicates the income of the rural household; Eci indicates whether the rural household carries out an e-commerce operation; Xi is the control variable (individual characteristics, household characteristics, and village characteristics); α is the constant term; β is the coefficient of the core independent variable; λ is the coefficient of the control variable; and ε is the error term.

3.3.2. Benchmark Regression Model

In order to further verify the intermediate transmission mechanism between e-commerce operation and farmers' income, with reference to the studies of Baron and Kenny [40], this study established the following mediation effect model:

$$Yi = \alpha 0 + \alpha 1\ Eci + \alpha 2 Xi + \varepsilon i \quad (2)$$

$$Zit = \delta 0 + \delta 1 Eci + \delta 2 Xi + \varepsilon i \quad (3)$$

$$Yi = \beta 0 + \beta 1 Zi + \beta 2\ Eci + \beta 3 Xi + \varepsilon i \quad (4)$$

where Z_{it} represents the mediating variables, including enhancing information acquisition, reducing operating costs, and enhancing financial support. α_1 represents the total effect of e-commerce operation on farmers' income; β_2 reflects the direct effect of e-commerce operation on farmers' income; $\delta_1\ \beta_1$ represents the size of the mediating effect; and $\delta_1\ \beta_1 / \alpha_1$ represents the proportion of the mediating effect to the total effect, which is used to reflect

the importance of the mediating variable in the income-enhancing effect of e-commerce operation. If α_1, β_1, and β_2 are all significant and β_2 is smaller than α_1, it indicates a partial mediation effect; if $\alpha 1$ and $\beta 1$ are all significant but β_2 is not significant, it indicates a full mediation effect.

4. Analysis of Empirical Results

4.1. Benchmark Regression Results

Using the Stata 17.0 software, a regression analysis was performed on the data according to Formula 1. The regression results of e-commerce operation on the total and per capita income of farming households are shown in Table 2. Columns (1), (2), and (3) show the regression results of adding individual characteristic variables, household characteristic variables, and village characteristic variables in turn. The results show that e-commerce operations all positively affect rural household income at the 1% significance level, indicating that e-commerce operations have a significant income-boosting effect, and participation in e-commerce is conducive to promoting the growth of rural household income. Thus, research hypothesis H1 is verified.

Table 2. The benchmark regression results of e-commerce operations on rural household income.

Variable Name	Total Household Income			Household per Capita Income		
	(1)	(2)	(3)	(1)	(2)	(3)
E-commerce operation	0.518 ***	0.479 ***	0.477 ***	0.477 ***	0.478 ***	0.476 ***
	(0.079)	(0.077)	(0.076)	(0.077)	(0.076)	(0.762)
Gender	−0.225 **	−0.266 ***	−0.260 ***	−0.321 ***	−0.296 ***	−0.291 ***
	(0.096)	(0.093)	(0.093)	(0.094)	(0.093)	(0.093)
Age	0.036 ***	0.033 ***	0.033 ***	0.034 ***	0.031 ***	0.031 ***
	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)	(0.010)
Square term of age	−0.048 ***	−0.044 ***	−0.044 ***	−0.042 ***	−0.040 ***	−0.040 ***
	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)	(0.009)
Marital status	0.344 **	0.058	0.008	−0.243	−0.090	−0.141
	(0.168)	(0.164)	(0.164)	(0.164)	(0.164)	(0.164)
Political affiliations	0.131 ***	0.117 **	0.123**	0.181 ***	0.116 **	0.124 **
	(0.049)	(0.049)	(0.049)	(0.048)	(0.049)	(0.049)
Health status	0.103 ***	0.100 ***	0.097 ***	0.102 ***	0.100 ***	0.097 ***
	(0.198)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Educational attainment	0.131 ***	0.123 ***	0.103 ***	0.123 ***	0.117 ***	0.098 ***
	(0.028)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
E-commerce training	0.291 ***	0.206 ***	0.216 ***	0.249 ***	0.205 ***	0.215 ***
	(0.079)	(0.077)	(0.077)	(0.077)	(0.007)	(0.077)
Number of family members		0.163 ***	0.166 ***		−0.090 ***	0.088 ***
		(0.013)	(0.013)		(0.013)	(0.013)
Number of family village cadres		0.151 **	0.169 ***		0.156 **	0.175 ***
		(0.062)	(0.062)		(0.062)	(0.062)
Family cooperative participation		0.190 ***	0.188 ***		0.188 ***	0.186 ***
		(0.045)	(0.045)		(0.045)	(0.044)
Village topography			−0.053 ***			−0.056 ***
			(0.016)			(0.016)
Geographic location of the village			0.066 ***			0.067 ***
			(0.050)			(0.049)
Distance of the village from the county government			−0.001			−0.001
			(0.001)			(0.001)
Constant term	9.525 ***	9.158 ***	9.390 ***	8.777 ***	9.030 ***	9.268 ***
	(0.324)	(0.316)	(0.322)	(0.318)	(0.316)	(0.321)
R^2	0.107	0.162	0.168	0.088	0.111	0.117
Sample size	2783	2783	2783	2783	2783	2783

Note: ** and *** indicate significance at the 5% and 1% levels, respectively; values in parentheses are standard errors.

Among the control variables, gender, age, square term of age, political affiliations, health status, education level, e-commerce training, household size, and the number of village cadres all significantly affect rural household income. Specifically, among the individual characteristics, the effect of income increase is more obvious for households with female heads. The age of the head of the household significantly and positively influences

the income of the rural household, while the age-squared shows a significant negative correlation. This indicates an inverted "U"-shaped relationship between the age of the head of the household and the income of the household. Political affiliations, health status and education level, and e-commerce training have significant positive effects on farmers' income, the latter because vocational skills training has a positive effect on improving human capital [41].

Regarding family characteristics, the number of family members, the number of family village cadres, and the participation in family cooperatives all have a significant positive impact on the income of rural households, which indicates that the stronger the family resource endowment, the higher the probability of rural households increasing their income, and at the same time, the participation in cooperatives helps farmers to expand their social resources; make full use of the technology, management, information, and other services provided by the cooperatives; and improve their income level.

Among the village characteristics, village topography has a significant negative effect on farmers' income, while village geographic location has a significant positive effect on farmers' income. The possible reasons for this are that, compared to plain areas, a mountainous terrain has poor transportation accessibility and natural resources, so the probability of farmers increasing their incomes is smaller; compared to non-urban peri-urban villages, urban peri-urban villages are more able to enjoy the capital, technology, talents, markets, and other resources introduced by the cities, and so there are more chances for farmers to work and start a business. Thus, the probability of increasing their incomes is higher.

4.2. Robustness Tests

4.2.1. Replacing the Core Independent Variables

In order to test the robustness of the above results, this study adopted the number of operating online stores as a measure of e-commerce operation and re-runs the regression analysis using the Stata 17.0 software. The results presented in Table 3 show that, after replacing the core independent variables, e-commerce operation still has a significant positive impact on farmers' income, which indicates that the previous regression results are robust.

Table 3. The robustness test results of e-commerce operation on farmers' income (replacing the core independent variables).

Variable Name	Total Household Income			Household per Capita Income		
E-commerce operation	0.468 *** (0.097)	0.439 *** (0.942)	0.455 *** (0.094)	0.427 *** (0.095)	0.421 *** (0.095)	0.440 *** (0.095)
Individual characteristic	control	control	control	control	control	control
Household characteristics		control	control		control	control
Village characteristics			control			control
Constant term	9.537 *** (0.326)	9.168 *** (0.317)	9.412 *** (0.323)	8.788 *** (0.319)	8.821 *** (0.318)	9.114 *** (0.323)
R^2	0.101	0.157	0.163	0.082	0.090	0.099
Sample size	2783	2783	2783	2783	2783	2783

Note: *** indicates significance at the 1% level, respectively; values in parentheses are standard errors.

4.2.2. Shrinkage Treatment

In order to exclude the influence of extreme values and further verify the robustness of the previous findings, this study conducted a bilateral shrinkage treatment at the 1% quantile on the total and per capita household incomes of rural households. The results presented in Table 4 results show that e-commerce operation still has a signifi-

cant positive impact on rural household income, further confirming the robustness of the previous findings.

Table 4. The robustness test results of the effect of e-commerce operation on farmers' income (shrinkage treatment).

Variable Name	Total Household Income			Household per Capita Income		
E-commerce operation	0.490 *** (0.075)	0.475 *** (0.075)	0.473 *** (0.075)	0.449 *** (0.074)	0.437 *** (0.073)	0.436 *** (0.073)
Individual characteristic	control	control	control	control	control	control
Household characteristics		control	control		control	control
Village characteristics			control			control
Constant term	9.541 *** (0.309)	9.575 *** (0.308)	9.745 *** (0.314)	8.797 *** (0.302)	8.828 *** (0.301)	9.104 *** (0.307)
R^2	0.111	0.121	0.162	0.090	0.099	0.106
Sample size	2783	2783	2783	2783	2783	2783

Note: *** indicates significance at the 1% level; values in parentheses are standard errors.

4.3. Endogeneity Test

4.3.1. Mutual Causality

There may be an endogeneity of mutual causality between e-commerce operation and farmers' income. On the one hand, e-commerce operation increases farmers' income by expanding the sales range, reducing the cost of sales, and enhancing the information and financial support; on the other hand, after the farmers' income is improved, it can provide more financial support for e-commerce operation, which is conducive to the expansion of the e-commerce operation scale. For this reason, this study adopted the 2SLS (Two-Stage Least Square) model for re-estimation. Referring to the study by Ma and Wang [42], this study selected the proportion of e-commerce operations of other farmers in the village as an instrumental variable. Due to the existence of the "peer effect", the proportion of e-commerce operations of other farmers in the village affects the e-commerce operation behavior of the farmers but does not directly affect the income level of the farmers, which meets the requirements of relevance and exogeneity of instrumental variables and is reasonable.

The results of the endogeneity test of e-commerce operation on farmers' income are shown in Table 5. The *p*-value of the Hausman test is 0.000, indicating that the original hypothesis that the core explanatory variables are exogenous is rejected at the 1% significance level, i.e., there is an endogeneity problem. The first-stage regression results show that the F-statistic value is greater than the critical value of 10, indicating no problem with weak instrumental variables [43]. The second-stage regression results show that, after considering the endogeneity problem of mutual causality, e-commerce operation still has a significant positive impact on farmers' income, which further validates the reliability of the findings of this study.

Table 5. The results of e-commerce operation 2SLS regression on rural household income.

Variable Name	Total Household Income		Household per Capita Income	
	First-Stage Regression	Second-Stage Regression	First-Stage Regression	Second-Stage Regression
E-commerce operation		1.767 *** (0.334)		1.752 *** (0.333)
Proportion of e-commerce operations by other farmers in the village	0.591 *** (0.046)		0.591 *** (0.046)	

Table 5. *Cont.*

Variable Name	Total Household Income		Household per Capita Income	
	First-Stage Regression	Second-Stage Regression	First-Stage Regression	Second-Stage Regression
Control variable	control	control	control	control
F-statistic	21.63		23.05	
R^2	0.111	0.086	0.111	0.028
Hausman test *p*-value	0.000 ***		0.000 ***	
Sample size	2783		2783	

Note: *** indicates significance at the 1% level; values in parentheses are standard errors.

4.3.2. Self-Selection Bias

Considering that e-commerce operation is a behavior self-selected by farmers, the previous model may have the endogeneity problem caused by self-selection bias. Propensity score matching (PSM) can effectively solve this problem. Propensity score matching (PSM) was first proposed by Rosenbaum et al. [44] and applied in biostatistics. Based on the control group samples, a natural experiment can be obtained if the corresponding non-e-commerce-operating farmers can be matched or constructed for each e-commerce-operating farmer and made to have approximately the same characteristics as the samples except for differences in e-commerce-operating choices. The net effect of e-commerce operations on farmers' incomes is derived by comparing the income differences between the two groups.

Therefore, in order to avoid the estimation bias caused by the self-selection problem, this study adopted the propensity score matching method for re-estimation to obtain the average treatment effect (ATT) of the impact of e-commerce operation on the income of rural households. The results presented in Table 6 show that the e-commerce operation has a significant positive effect on rural household income, whether estimated by the propensity score matching method such as nearest neighbor matching, radius matching, caliper matching, kernel matching, local linear regression matching, or Mars matching.

Table 6. The PSM regression results of the effect of e-commerce operation on farmers' income.

Matching Method	Total Household Income			Household per Capita Income		
	Experimental Group	Control Group	ATT	Experimental Group	Control Group	ATT
One-to-one near neighbor matching	11.464	11.049	0.415 ***	10.044	9.667	0.378 ***
K-nearest neighbor matching	11.464	11.064	0.400 ***	10.044	9.646	0.399 ***
Radius matching	11.464	10.762	0.702 ***	10.044	9.406	0.638 ***
One-to-four matching in caliper	11.456	11.051	0.405 ***	10.038	9.635	0.403 ***
Kernel matching	11.464	10.942	0.522 ***	10.044	9.545	0.499 ***
Local linear regression matching	11.464	10.986	0.478 ***	10.044	9.572	0.472 ***
Marginal matching	11.464	11.055	0.409 ***	10.044	9.673	0.371 ***

Note: *** indicates significance at the 1% level; values in parentheses are standard errors.

The PSM model specification must satisfy the two prerequisites of overlap assumption and equilibrium properties [45]. For the overlap assumption, the public support domain needs to be tested, and Figure 3 shows the distribution of propensity scores for testing the public support domain. After matching, the e-commerce and non-e-commerce operation samples almost overlap in the propensity scores, and there are large common support intervals, indicating that the matching is more reasonable.

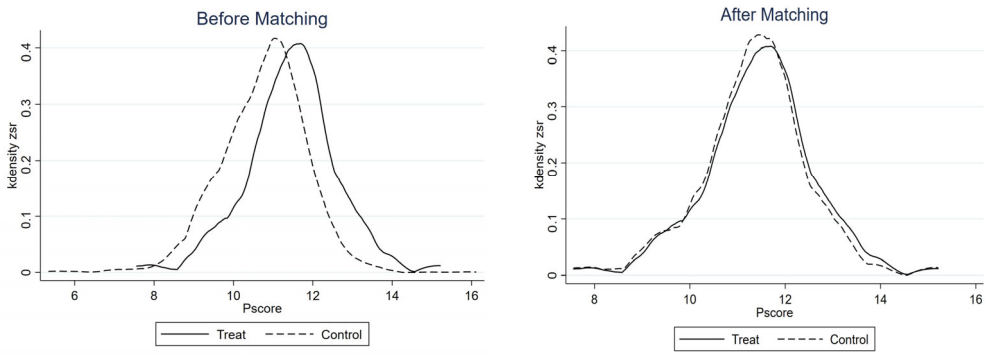


Figure 3. The distribution of propensity scores before and after matching.

In order to examine whether the above propensity score matching estimation results balance the data better, a balance test is needed. The results of the balance test are shown in Table 7. In this study, using the one-to-one nearest-neighbor matching method as an example, the results show that, compared to the pre-matching period, the standardized deviation rates of the control variables are all reduced after matching, and the standardized deviation rates are all less than 10%. Meanwhile, none of the *t*-test results of the control variables reject the original hypothesis that there is no systematic difference between the experimental group and the control group, effectively balancing the differences in the distribution of covariates between the experimental group and the control group. Therefore, the propensity score matching results passed the balance test.

Table 7. The balance test for control variables.

Control Variable	Pre-Match Average		Average Value after Matching		Deviation Rate (%)		Post-Matching *t*-Test	
	Experimental Group	Control Group	Experimental Group	Control Group	Before Matching	After Matching	*t*-Value	$p > t$
Gender	0.955	0.956	0.955	0.950	−0.5	2.4	0.23	0.815
Age	52.146	55.281	55.146	52.263	−28.8	−1.1	−0.11	0.911
Square term of age	28.224	31.890	28.224	28.389	−31.2	−1.4	−0.15	0.882
Marital status	0.985	0.986	0.985	0.980	−0.7	4.2	0.38	0.704
Educational attainment	2.101	1.834	2.101	2.157	33.8	−7.0	−0.65	0.515
Political affiliations	0.328	0.238	0.328	0.338	20.0	−2.3	−0.21	0.832
Health status	3.687	3.600	3.687	3.732	9.6	−4.5	−0.46	0.646
E-commerce training	0.278	0.058	0.278	0.268	61.4	2.8	0.23	0.822
Number of families	4.379	4.169	4.379	4.253	14.6	8.8	0.89	0.375
Number of family village cadres	0.172	0.109	0.172	0.157	18.0	4.3	0.41	0.685
Family cooperative participation	0.374	0.249	0.374	0.404	27.2	−6.6	−0.62	0.537

Table 7. *Cont.*

Control Variable	Pre-Match Average		Average Value after Matching		Deviation Rate (%)		Post-Matching *t*-Test	
	Experimental Group	Control Group	Experimental Group	Control Group	Before Matching	After Matching	*t*-Value	*p* > *t*
Village topography	2.222	2.225	2.222	2.152	−0.2	5.4	0.54	0.591
Geographic location of the village	0.237	0.206	0.237	0.273	7.6	−8.5	−0.81	0.421
Distance of the village from the county government	24.201	23.146	24.201	23.3	6.1	5.2	0.50	0.617

4.4. Mechanism Analysis

Based on the previous theoretical analysis, e-commerce operation impacts farmers' income through three paths: enhancing information acquisition, reducing operating costs, and enhancing financial support. To this end, the mediating-effect method was used to verify the above action mechanisms via the Stata 17.0 software, and the results are shown in Table 8. The results show that e-commerce operation promotes the growth of rural household income by enhancing information acquisition, reducing operating costs, and enhancing financial support, and the research hypothesis H2 is verified. As calculated from the regression results, enhancing information acquisition, reducing operating costs, and enhancing financial support play a partial mediating role in the relationship between e-commerce operation and the total income of farming households, with the mediating effect accounting for 10.45%, 28.12%, and 13.14%, respectively. They also play a partial mediating role in the relationship of e-commerce operation affecting the per capita income of farming households, with the mediating effect accounting for 8.67%, 25.44%, and 12%.

Table 8. The mechanism test results of the effect of e-commerce operation on farmers' income.

Variable Name	Total Household Income						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Total Household Income	Enhanced Information Acquisition	Total Household Income	Reduced Operating Costs	Total Household Income	Enhanced Financial Support	Total Household Income
E-commerce operation	0.477 *** (0.076)	0.214 *** (0.077)	0.652 *** (0.078)	0.261 *** (0.035)	0.575 *** (0.080)	0.154 *** (0.040)	0.581 *** (0.083)
Enhanced information acquisition			0.233 *** (0.019)				
Reduced operating costs					0.514 *** (0.043)		
Enhanced financial support							0.407 *** (0.045)
Control variable	control	control	control	control	control	control	control
Constant term	9.390 *** (0.322)	3.983 *** (0.020)	9.832 *** (0.080)	0.325 *** (0.010)	10.590 *** (0.025)	0.497 *** (0.011)	10.636 *** (0.033)
R^2	0.168	0.002	0.076	0.020	0.076	0.007	0.062
Sample size	2783	2783	2783	2783	2783	2783	2783

Table 8. *Cont.*

Variable Name	Household per Capita Income						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	Household per Capita Income	Enhanced Information Acquisition	Household per Capita Income	Reduced Operating Costs	Household per Capita Income	Enhanced Financial Support	Household per Capita Income
E-commerce operation	0.476 *** (0.762)	0.214 *** (0.077)	0.597 *** (0.076)	0.261 *** (0.035)	0.517 *** (0.077)	0.154 *** (0.040)	0.525 *** (0.081)
Enhanced information acquisition			0.193 *** (0.019)				
Reduced operating costs					0.464 *** (0.042)		
Enhanced financial support							0.371 *** (0.044)
Control variable	control	control	control	control	control	control	control
Constant term	9.268 *** (0.321)	3.983 *** (0.020)	8.639 *** (0.078)	0.325 *** (0.010)	9.247 *** (0.024)	0.497 *** (0.011)	9.289 *** (0.031)
R^2	0.117	0.002	0.059	0.020	0.067	0.007	0.055
Sample size	2783	2783	2783	2783	2783	2783	2783

Note: *** indicates significance at the 1% level; values in parentheses are standard errors.

4.5. Heterogeneity Analysis

In order to examine the heterogeneity of the impact of e-commerce operations on the income of rural households in different groups and regions, this study conducted group regression on the samples from the level of the income structure, education level, and regional distribution, respectively. The results show that the impact of e-commerce operations on rural household income is heterogeneous in terms of income structure, education level, and regional distribution, and research hypothesis H3 is verified.

4.5.1. Heterogeneity Analysis Based on Rural Household Income Structure

Drawing on study of Li et al. [14] and combining the existing data indicators, this study decomposed the income structure of rural households into agricultural business income, non-agricultural business income, wage income, property income, and transfer income. The results of the impact of e-commerce operations on the different incomes of rural households are presented in Table 9. The results show that e-commerce operation has a significant positive impact on rural household agricultural business income, non-agricultural business income, and transfer income; a significant negative impact on rural household wage income; and no significant impact on rural household property income.

Table 9. The heterogeneity analysis regression results for different income structures.

Variable Name	Total Household Income				
	Agricultural Business Income	Non-Farm Business Income	Wage Income	Property Income	Transfer Income
E-commerce operation	0.878 *** (0.150)	1.668 *** (0.248)	−0.261 * (0.143)	0.0223 (0.022)	02152 ** (0.109)
Control variable	control	control	control	control	control
Constant term	6.261 *** (0.628)	2.270 *** (1.042)	7.186 *** (0.601)	4.789 *** (0.853)	9.005 *** (0.458)
R^2	0.089	0.065	0.106	0.060	0.070
Sample size	2783	2783	2783	2783	2783

Table 9. *Cont.*

Variable Name	Household per Capita Income				
	Agricultural Business Income	**Non-Farm Business Income**	**Wage Income**	**Property Income**	**Transfer Income**
E-commerce operation	0.878 *** (0.149)	1.667 *** (0.248)	−0.262 * (0.142)	0.021 (0.202)	0.214 * (0.109)
Control variable	control	control	control	control	control
Constant term	6.139 *** (0.627)	2.148 *** (1.043)	7.063 *** (0.599)	4.666 *** (0.852)	8.882 *** (0.460)
R^2	0.094	0.060	0.052	0.091	0.137
Sample size	2783	2783	2783	2783	2783

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% statistical levels, respectively; values in parentheses are standard errors.

4.5.2. Heterogeneity Analysis Based on Educational Attainment of Rural Households

Drawing on the study by Oddo et al. [46], this study divided the education level of household heads into two groups: a low education level (junior high school and below) and high education level (above junior high school). The results of the impact of e-commerce operation on farmers' income under different education levels are presented in Table 10. The results show that e-commerce operation has a more obvious effect on farmers' income with high education levels than those with low education levels, probably because e-commerce operation requires digital skills as support, and farmers with high education levels have an advantage in digital technology learning, etc., and are better able to profit from e-commerce operation.

Table 10. The heterogeneity analysis regression results by education level.

Variable Name	Total Household Income		Household per Capita Income	
	Low Educational Attainment	**High Educational Attainment**	**Low Educational Attainment**	**High Educational Attainment**
E-commerce operation	0.417 *** (0.088)	0.628 *** (0.160)	0.418 *** (0.088)	0.636 *** (0.159)
Control variable	control	control	control	control
Constant term	9.312 *** (0.357)	9.067 *** (0.972)	9.201 *** (0.356)	8.855 *** (0.976)
R^2	0.162	0.180	0.098	0.184
Sample size	2315	468	2315	468

Note: *** indicates significance at the 1% level; values in parentheses are standard errors.

4.5.3. Heterogeneity Analysis Based on the Regional Distribution of Rural Households

Drawing on study by Wang et al. [47], this study divided the 24 provinces into three regions, east, central, and west, based on the criteria for dividing the level of economic development and conducted group regressions for the eastern, central, and western regions. The results of the impact of e-commerce operations on farmers' income under different regional distributions are presented in Table 11. The results show that the effect of e-commerce operation on farmers' income in the central and western regions is more obvious than that of farmers in the eastern region. This suggests that e-commerce operations help to bridge the development gap between regions and reduce the income gap within rural areas between regions.

Table 11. The heterogeneity analysis regression results for different regional distributions.

Variable Name	Total Household Income		Household per Capita Income	
	Eastern Part	Central and Western Region	Eastern Part	Central and Western Region
E-commerce operation	0.298 ** (0.152)	0.486 *** (0.089)	0.306 ** (0.152)	0.476 *** (0.088)
Control variable	control	control	control	control
Constant term	9.018 *** (0.610)	9.430 *** (0.381)	9.037 *** (0.606)	9.242 *** (0.381)
R^2	0.226	0.157	0.182	0.100
Sample size	740	2043	740	2043

Note: ** and *** indicate significance at the 5% and 1% statistical levels, respectively; values in parentheses are standard errors.

5. Research Findings and Policy Implications

5.1. Research Conclusions

Based on the 2020 China Rural Revitalization Survey data, this study empirically analyzed the impact of e-commerce operations on farmers' income using the OLS model and the mediation effect model. Based on the above analysis, this study draws the following three conclusions.

Firstly, e-commerce operation can significantly increase rural household income, and the research results are robust. E-commerce operation expanded the sales channels and market scope for farmers' agricultural products, providing new sales models and ideas. At the same time, it significantly compressed the intermediate links of the traditional "producer–purchaser–wholesaler–retailer" model, reduced the harm of intermediaries to farmers' interests, and promoted an increase in farmers' income.

Secondly, e-commerce operations can increase farmers' income through three paths: strengthening information acquisition, reducing operating costs, and enhancing financial support. These factors play a partial mediating role in the relationship between e-commerce operations and the total household income of farmers, with mediating effects accounting for 10.45%, 28.12%, and 13.14%, respectively. This indicates that factors such as information and funding are not only key to promoting the development of e-commerce but also indirectly promoting an increase in farmers' income. At the same time, making full use of the market operation rules and price competition mechanism of the Internet can reduce production and operation costs and encourage farmers to obtain e-commerce operating dividends.

Thirdly, the impact of e-commerce operation on farmers' income is heterogeneous in terms of income structure, education level, and regional distribution. Specifically, e-commerce operation has a significant positive impact on rural household agricultural business income, non-farm business income, and transfer income and a significant negative impact on rural household wage income; it has a more obvious role in increasing the income of highly educated rural households; and it has a better effect of increasing the income of rural households in the central and western regions, which suggests that e-commerce operation plays a positive role in promoting the development of backward regions and helps to narrow the regional development gap, showing good inclusiveness.

5.2. Policy Implications

Based on the above research conclusions, this study draws the following three policy insights.

Firstly, it is important to improve the supporting facilities for e-commerce in rural areas, especially processing and logistics facilities; promote the synergistic development of e-commerce for agricultural production materials, e-commerce for agricultural products, and e-commerce for rural consumer goods; and efficiently support the production and business activities of farmers and the development of the rural economy. At the same time, it is important to optimize the e-commerce operation environment, cultivate e-commerce

sales talents, stimulate the potential for the development of rural e-commerce, and promote the in-depth fusion of the rural real economy and digital economy and build a long-term mechanism for rural e-commerce to help farmers increase their income [48].

Secondly, the goal should be enhancing the supply of information, capital, and other factors; fully releasing the potential of rural e-commerce to increase income; improving the institutional mechanism of e-commerce operation; eliminating the obstacles to farmers' access to information, capital, and other factors by building an information platform and establishing a long-term mechanism of digital finance to the countryside; and, at the same time, building an integrated e-commerce service platform for production, processing, logistics, and sales to further reduce the transaction costs of raw materials and products and provide a solid guarantee for a steady increase in farmers' income. This will provide a solid guarantee for farmers to steadily increase their income.

Thirdly, it is important to improve the inclusiveness of rural e-commerce and bridge the "digital divide" between groups and regions. For disadvantaged groups with low education levels, the government should actively expand the coverage of e-commerce training, optimize the content of e-commerce training and technology supply, enhance their comprehensive digital literacy and awareness of using e-commerce platforms to increase their income, and reduce the phenomenon of uneven sharing of the "digital dividend". At the same time, for less developed regions, the government should continue to promote the supply of digital resources and strengthen the fair sharing of rural e-commerce benefits [49].

5.3. Discussion

In the context of the digital economy era, this study utilized data from the 2020 China Rural Revitalization Survey and employed the OLS and mediation effects models to explore the impact and mechanism of e-commerce operations on farmers' income. Furthermore, it examined the heterogeneous impact of e-commerce operations on farmers' income and proposes policy recommendations based on these findings.

The results indicate that e-commerce operations can significantly increase farmers' income. This finding is consistent with previous research, emphasizing the role of e-commerce in promoting farmers' income growth. E-commerce has become a new channel for supporting farmers' income growth, which is consistent with the research results of multiple scholars [18]. Factors such as education, e-commerce training, family size, number of village cadres, and participation in family cooperatives also significantly affect farmers' income, which is consistent with the research results of Magagua and Awodiji and Li et al. [14,41]. E-commerce operations promote farmers' income growth by enhancing information acquisition, reducing operating costs, and strengthening financial support, consistent with the research findings of Majhi and Angmo [29,34]. The impact of e-commerce on farmers' income exhibits heterogeneity in income structure, education level, and regional distribution, which is similar to the findings of Qi and Qin and Fang [38,39].

Compared to the existing literature, the marginal contributions of this study are as follows: Firstly, based on the 2020 China Rural Revitalization Survey data, we discussed the income-increasing effect of e-commerce in China from the micro-perspective of farmers, which can reveal the problems and needs of specific groups or regions that may be masked by macro-data and provide new directions for formulating policies for the development of e-commerce in China. Secondly, we focused on the development of e-commerce at the national level, with a wide coverage of survey samples, guaranteed representativeness and robustness of research conclusions, and good external effectiveness of proposed policies. Thirdly, we identified the income-increasing effects and paths of farmers' e-commerce operations and examined the impact mechanism of e-commerce operations on farmers' income from multiple paths. An empirical analysis was also conducted on the endowment differences between different farmers and regions. The research conclusions provide a reference for other developing countries and regions to explore the use of digital economy to promote rural development and increase farmers' income and have important reference

significance for promoting the healthy development of the rural digital economy and poverty alleviation of rural households in developing countries.

Limitations and future research directions of this study: This study empirically analyzed the impact of e-commerce operations on farmers' income, which has important theoretical significance and practical value, but there are still some shortcomings. One limitation is the limited availability of data (the second phase of the China Rural Revitalization Survey data has not yet been released), which prevents cross-year, multi-period tracking data, thus limiting the applicability of the conclusions drawn in this study. Secondly, the impact of farmers' income is a common result of multiple factors, with e-commerce being one. Due to data limitations, the core independent variable used in this study was whether products are sold online to measure e-commerce operations. The comparison is simple, but further exploration and refinement are needed. Therefore, future research should examine the following two aspects: On the one hand, using multi-period tracking survey data to further ensure the timeliness and applicability of the research. The second goal should be to explore the impact of expanding farmers' e-commerce operations on their income growth, such as what online platforms farmers use to sell their products, which agricultural products are more suitable for online sales, what marketing strategies are more effective in increasing farmers' income, and the impact of farmers' activity on social media platforms on their income, etc., which are all directions that should be explored in the future.

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