MDPI

Article

The Influence of Digital Literacy on the Phenomenon of Deviation between Farmers' E-Commerce Sales Willingness and Behavior: Evidence from Rural China

Yonghu Zhang [ID] and Yifeng Zhang *[ID]

College of Economics and Management, Nanjing Forestry University, Nanjing 210037, China; zyh158@njfu.edu.cn
* Correspondence: yifzhang@njfu.edu.cn

Abstract: E-commerce, as a prominent feature of the digital economy era, is highly expected to promote economic growth and sustainable development. Based on the 2020 "China Rural Revitalization Survey" data, this study empirically analyzed the impact and mechanism of digital literacy on the discrepancy between the willingness and behavior of farmers in e-commerce sales. Eleven indicator items were selected, and factor analysis was used to obtain the comprehensive score of digital literacy. Firstly, benchmark regression was performed using the probit model, and then potential endogeneity issues were addressed using the IV probit method and endogenous conversion probit model. The following main conclusions were drawn: Digital literacy has a suppressive effect on the deviation between the willingness and behavior of farmers in e-commerce sales. Farmers with media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy have a 12.3%, 18.3%, 26.2%, 37.5%, and 21.9% reduction in the probability of deviation between the willingness and behavior of farmers in e-commerce sales compared to those without these literacy counterfactual assumptions. Digital literacy helps curb the deviation between farmers' willingness and behavior in e-commerce sales by facilitating their access to financial resources and agricultural production services. This study demonstrates that enhancing the digital literacy of farmers will promote their willingness to convert e-commerce sales into behavior, help promote sustainable agricultural products more efficiently, and make important contributions to economic growth and sustainable development.

Keywords: digital economy; digital literacy; rural e-commerce; financial acquisition; agricultural production services

1. Introduction

The digital economy is a significant trend in today's world economic development, spurring technological innovation and industrial transformation [1]. It profoundly impacts economic growth and sustainable development. E-commerce, a key aspect of the digital economy, enhances production efficiency [2], improves consumer experiences [3], and fosters innovation and employment [4]. In rural areas, e-commerce offers farmers broader markets and more efficient sales channels [5,6], leading to higher incomes for adopters compared to non-adopters. Studies confirm this significant income increase [7]. The digital economy can promote green development and reduce the environmental damage caused by traditional industries [8]. Through the application of digital technology, energy consumption can be reduced, carbon emissions can be reduced, the circular economy can be promoted, and sustainable development can be promoted [9]. Research has confirmed that e-commerce can promote regional fertilizer reduction [10], alleviate agricultural non-point source pollution [11], and help promote sustainable agricultural product consumption [12]. In summary, promoting the adoption of e-commerce sales by farmers is of great significance and will promote sustainable development.

Taobao Village refers to a village where the number of active online stores reaches more than 10% of local households and the annual transaction volume of e-commerce reaches more than 10 million yuan. In 2021, Taobao Village only accounted for 1.0% of China's 691,510 administrative villages, and the penetration rate of rural e-commerce is still relatively low [13,14]. In 2020, data from a national rural household survey initiated by the Institute of Rural Development of the Chinese Academy of Social Sciences showed that the deviation ratio between farmers' willingness to sell e-commerce and their actual behavior was about 77%, indicating a significant gap between willingness and actual behavior. Research by Li et al. (2021) also highlights the prominent phenomenon of the deviation between the intention and behavior of Chinese rural households in e-commerce [15]. China urgently needs to take more effective measures to improve the adoption rate of online sales.

In some countries, there are many problems with the development of the digital economy [16], the legal norms of the e-commerce industry are not yet perfect, and the rights and interests of consumers are not protected [17,18]. The relevant laws on e-commerce in China are already relatively complete. The first e-commerce law implemented in 2019, the E-commerce Law of the People's Republic of China, regulates the behavior of e-commerce entities with professional provisions and encourages, supports, and guides the development of rural e-commerce. This article relies on legal provisions to conduct the relevant research.

Existing literature mainly focuses on the influencing factors of farmers' willingness or behavior in e-commerce sales, with relatively fewer studies examining both willingness and behavior. On a macro level, village information infrastructure [19,20], policy systems [21], and other factors can impact whether farmers adopt e-commerce sales; on a micro level, factors such as farmers' education level, land resources, household annual income [15], social capital [13], and membership in cooperatives all influence farmers' adoption of e-commerce. Studies by Li et al. (2021) have explored the impact of rural environment and capital endowment on farmers' willingness and behavior in e-commerce sales [13], but empirical analysis specifically addressing the phenomenon of deviation between willingness and behavior is lacking. The existing literature provides a reference for studying the phenomenon of deviation between farmers' willingness and behavior in e-commerce sales, but there are still many directions for further research.

The digital divide makes it difficult for a part of the population to integrate into the digital economy and participate in e-commerce practices, especially in rural areas, where agricultural production is of great significance for sustainable development, and the difficulty for farmers to integrate into the digital economy can have a negative impact on sustainable development. There is a certain digital threshold to enter the e-commerce industry [22], and a high level of digital literacy support is needed to apply digital technology and integrate into the digital economy [23,24]. The impact of digital literacy on e-commerce sales for rural households should not be underestimated.

The concept of digital literacy was first proposed by ESHET-ALKALAI et al. (2004) [25] and was defined as the essential skills needed for citizens to live, learn, and work in the emerging digital environment. Research has also indicated that digital literacy encompasses the ability to access and effectively search for information online [26,27]. UNESCO has outlined the evolution of digital literacy, which includes media literacy, information literacy, digital competency, and digital literacy, and has identified seven domains of literacy, including operational, informational, communicative, content creation, security and ethics, problem-solving, and professional domains. Although digital literacy is considered a general term, its boundaries are still blurry [28], and there is no consensus on its definition. This is because the required digital literacy may vary in different application scenarios and for different individuals. Based on this, this study defines digital literacy as the comprehensive multidimensional ability to apply digital technology in the emerging digital environment, which has the characteristics of adapting to different scenarios and dynamic development.

Ma et al. (2020) [29] and Song et al. (2023) [30] have shown that farmers' use of the internet has a significant positive effect on improving their information literacy and promoting online sales. However, it is regrettable that there is currently limited literature

explicitly proposing the impact of digital literacy on farmers' e-commerce sales and further research on its underlying impact mechanisms. Ariansyah et al. (2021) [31] found that having sufficient digital skills increases the likelihood of using e-commerce for online shopping, but the study did not reveal the impact of digital literacy on e-commerce sales. These studies provide the basis for the present research, through which this paper introduces the variable of digital literacy and empirically explores its impact on the intention and behavior of farmers' e-commerce sales.

Currently, further research is needed on the mechanism through which digital literacy affects e-commerce sales for farmers. Small-scale farmers participating in e-commerce sales face barriers such as a lack of funds, technology, and labor [32,33]. Farmers with digital literacy are more easily able to access financial [34,35] and agricultural production services [36,37] through formal channels, enabling them to overcome the barriers of insufficient funds, technology, and labor for participating in e-commerce sales and leading to the transformation of e-commerce sales intention into behavior. Based on this, the present study explores the financial access mechanism and agricultural production service access mechanism through which digital literacy impacts the deviation between farmers' e-commerce sales intention and behavior.

The research question of this article is whether digital literacy will inhibit the phenomenon of the deviation between farmers' willingness and behavior in e-commerce sales, and what is the impact mechanism. In summary, this paper aims to make the following contributions: First, based on the micro perspective of farmers, explore the impact of digital literacy on the discrepancy between farmers' e-commerce sales willingness and behavior, filling the research gap and improving the relevant theories of factors influencing farmers' e-commerce sales. Second, it investigates the potential mediating effects of financial access and agricultural production service access on the impact of digital literacy on the deviation between farmers' e-commerce sales intention and behavior, thus supplementing the research on the impact mechanism of digital literacy on e-commerce sales. Third, it discusses both e-commerce sales willingness and e-commerce sales behavior, with a view to making relevant recommendations for solving the paradox of e-commerce willingness and behavior that exists in China and promoting greater participation of farmers in e-commerce practices so as to contribute to economic growth and sustainable development. Fourth, it utilizes the China Rural Revitalization Survey data initiated by the Rural Development Institute of the Chinese Academy of Social Sciences in 2020 and employs probit models for regression analysis, as well as IV-probit methods and endogenous switching probit models to address potential endogeneity issues.

The following sections are structured as follows: first, the theoretical analysis and research hypotheses, followed by the materials and methods section. Then, the empirical results and discussion section. Finally, the paper concludes with a section on summary and policy recommendations.

2. Theoretical Analysis and Research Hypotheses

2.1. The Effect of Digital Literacy on Farmers' E-Commerce Sales Willingness and Behavior Deviation

This article is based on the definition of digital literacy, the actual needs of farmers in the digital environment, and the application scenario of e-commerce participation. It adopts the connotation of digital literacy proposed by UNESCO to construct five dimensions of media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy to describe digital literacy.

This article examines the issue of the conversion of farmers' e-commerce sales intentions into actions, specifically how farmers can transition from having "intention without action" to "intention with action". In this article, farmers' e-commerce sales refer to farmers selling their products through online platforms, and the discrepancy between farmers' e-commerce sales intentions and actions refers to farmers having the intention to sell online but not taking actual action.

This article analyzes the farmers' behavior based on the theory of rational peasant economics. According to this theory, farmers are rational economic agents, and the ultimate goal of their production decisions is to maximize profits. Therefore, the economic value of participating in e-commerce sales is the driving force for farmers to transition from having the intention to participate in e-commerce sales to actually engaging in sales activities.

Media operation literacy refers to farmers' ability to proficiently use digital tools and applications, such as operating smartphones, using the internet, and making online payments. By mastering these skills, farmers can efficiently integrate resources, reduce transaction costs [38,39], and successfully participate in e-commerce sales, thereby increasing their income. Since e-commerce is conducted through digital media, media literacy is essential for farmers to engage in e-commerce activities.

Information acquisition literacy refers to farmers' ability to access information through media at any time and meet their daily needs. In the digital age, farmers face a vast amount of complex information. Information literacy helps farmers overcome the constraints of remote rural areas, better access and filter information related to e-commerce [30], reduce information search costs, alleviate information asymmetry issues [40], and improve the consistency of e-commerce sales intentions and actions.

Digital transaction literacy refers to farmers' ability to conduct transactions through digital media. On one hand, e-commerce transactions generally take place online, and whether farmers grasp the process of digital payment determines whether they can complete e-commerce transactions. On the other hand, for farmers, online platforms offer more convenient access to services compared to offline platforms [41]. Having digital transaction literacy means that farmers can access knowledge, technology, funds, and other services online when needed [31], breaking down barriers such as insufficient knowledge, technology, labor, and funds for participating in e-commerce sales.

E-commerce cognition literacy refers to farmers' level of understanding of e-commerce. By improving farmers' familiarity with e-commerce platforms through training and guidance services, farmers can better understand the operating rules and sales techniques of e-commerce platforms, gain more sales opportunities and competitive advantages [42], and thus convert their intention to participate into actual behavior. On the other hand, farmers have relatively weak legal knowledge and risk awareness, and e-commerce involves consumer data privacy [17,43]. Through training and other means, they can enhance their awareness of e-commerce, become familiar with relevant legal norms, protect their legitimate rights and interests, and participate in e-commerce sales while complying with relevant regulations, ensuring the sustainable and healthy development of farmers' e-commerce businesses.

Digital social literacy refers to farmers' potential to disseminate information through social channels such as WeChat, live streaming, and short videos. E-commerce is increasingly reliant on new social media platforms, and new formats such as live streaming e-commerce and short video e-commerce are thriving [44,45]. Farmers can expand their sales channels, increase customer interaction, enhance product exposure, and reduce marketing costs through new social media platforms [46,47], thereby increasing their enthusiasm for e-commerce sales.

Accordingly, Hypothesis 1 is proposed in this paper:

Hypothesis 1. *Digital literacy has a negative effect on farmers' e-commerce sales willingness and behavior deviation.*

2.2. Mediating Effects of Access to Finance

Based on the survey data used in this article, financial acquisition specifically refers to farmers applying for loans from formal banks (including rural credit cooperatives and rural banks).

Financial products are products with high information density, requiring investors to have good financial knowledge and risk judgment ability [48]. Farmers use digital

technology to alleviate the problem of information asymmetry [49]. Through digital platforms, farmers can obtain the latest knowledge about financial products, transaction methods, market information, etc., including the selection of financial products, loan processes, interest rate calculations, etc. [50], so as to better obtain financial products that meet their own needs.

The development of digital technology enables financial services to be more conveniently provided to farmers through channels such as mobile devices and the internet [51]. Thanks to the rapid development of information technology, the emergence of digital finance has brought new financial services and products [52], which can make up for the shortcomings of the traditional banking industry and enable underdeveloped areas to enjoy convenient financial services [53]. Farmers have a high level of digital literacy and possess the skills to use digital technology to access finance, thereby promoting financial access.

Digital technology can help farmers better manage their finances and risks [54,55], such as using electronic payments to simplify transaction processes, using mobile apps for financial recording and analysis, etc. If farmers can proficiently use these tools, they can improve financial management efficiency and promote financial access.

In the process of financial acquisition, farmers need to provide personal information, perform electronic payments, and perform other operations. High digital literacy can help farmers better identify and respond to cybersecurity risks, increase trust, and reduce concerns about financial access [56].

In summary, digital literacy plays an important role in promoting financial access for farmers. By improving their understanding and application ability of digital technology and financial knowledge, farmers can better access and manage financial resources.

Through financial means, farmers can obtain financial support to expand production scale, improve the quality of agricultural products [57], and carry out e-commerce business. E-commerce platforms usually require a certain amount of capital investment to establish online stores, purchase goods, promote products, etc. Financial services can provide loans, financing, and other support to farmers, helping them better participate in the e-commerce industry. In addition, the e-commerce industry poses significant risks [58], such as transaction risks and product quality issues. Financial institutions can provide risk management tools, such as insurance and guarantees, to help farmers reduce risks and losses [59]. Farmers receive support for risk management through financial services and are more confident and secure in participating in e-commerce businesses. In short, financial access provides financial support and risk management tools for farmers, which can promote their better participation in the e-commerce industry, promote online sales, and expand the market for agricultural products.

Accordingly, Hypothesis 2 is proposed in this paper:

Hypothesis 2. *Digital literacy will inhibit the deviation of farmers' e-commerce sales willingness and behavior by promoting farmers' financial access.*

2.3. Mediating Effect of Access to Agricultural Production Services

The agricultural production services discussed in this article refer to agricultural professional institutions (cooperatives, agricultural leading enterprises, etc.) replacing farmers in some or all of their agricultural production work. The advantage of such institutions conducting production is their ability to achieve economies of scale [60]. Small farmers face limitations in terms of technical and economic scale, resulting in inefficient allocation of resources [61]. Agricultural production services address these limitations, enabling farmers to achieve cost advantages and adopt environmentally friendly and cost-effective production methods [62,63]. As a result, the products produced can command a premium price [64], thereby enhancing the bargaining power of farmers in the market.

Due to the constraints of scattered markets and weak rural infrastructure, farmers' digital literacy leads them to rely on digital platforms to search for information, reducing the cost of accessing agricultural production services. Moreover, if farmers widely use

digital platforms, they can also lower the cost of monitoring agricultural production services. Farmers can obtain real-time data through digital platforms, improving monitoring efficiency. These platforms also make information on agricultural production services more transparent, alleviating information asymmetry issues.

Furthermore, existing research has shown that rural farmers with higher digital literacy tend to engage in non-agricultural employment [65], and engaging in e-commerce sales can be seen as non-agricultural employment. The shortage of agricultural labor prompts farmers to purchase agricultural production services to supplement labor and ensure agricultural income [63]. Obtaining agricultural production services liberates farmers from tedious agricultural work, saving labor and time costs and enabling them to better manage marketing activities. In summary, digital literacy plays an important role in facilitating farmers' access to agricultural production services.

Access to agricultural production services allows farmers to have more time and labor to engage in e-commerce sales. Engaging in e-commerce operations requires scaled-up production [66], so farmers supplement labor by acquiring agricultural production services. On the other hand, agricultural production service institutions possess richer production experience and specialized knowledge [67], tending to adopt environmentally friendly and cost-effective production methods [68]. This enhances the quantity and quality of agricultural products, reduces production risks for farmers, ensures the availability of suitable products for sale, and makes it easier for farmers to enter the e-commerce market.

Accordingly, Hypothesis 3 is proposed in this paper:

Hypothesis 3. *Digital literacy will inhibit the deviation of farmers' e-commerce sales willingness and behavior by promoting farmers' agriculture production service access. The theoretical framework of this study is shown in Figure 1.*
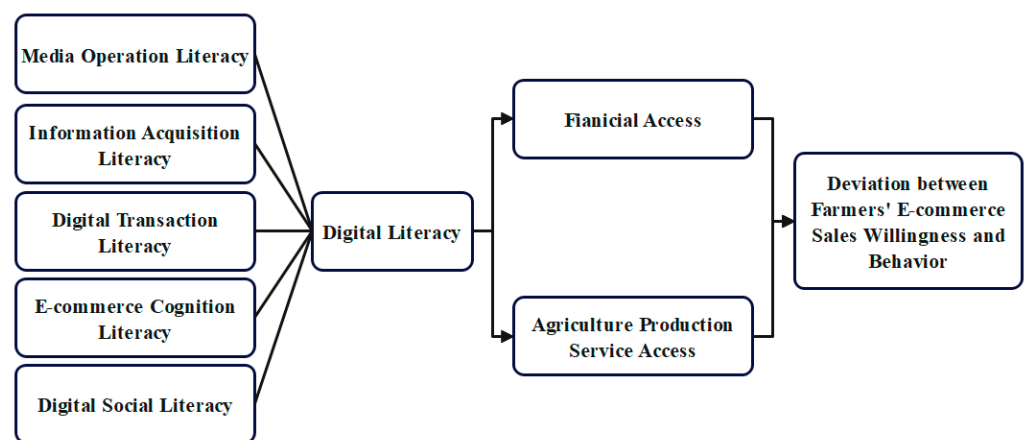

Figure 1. Theoretical Framework.

3. Materials and Methods

3.1. Data Source

The data used in this article was obtained through an application and is sourced from the China Rural Revitalization Survey (CRRS), launched by the Institute of Rural Development Chinese Academy of Social Sciences in 2020. This data is a comprehensive survey carried out in many fields, including agricultural production, rural development, farmers' lives, social welfare, and other aspects, with full representation. First, the project team comprehensively considers the level of social and economic development, agricultural and rural development, and geographical location and selects 10 sample provinces from eastern, central, western, and Northeast China, including Guangdong, Zhejiang, Shandong, Anhui, Henan, Guizhou, Sichuan, Shaanxi, Ningxia, and Heilongjiang, according to the proportion of one-third of the number of provinces in the region. The distribution of sample provinces is shown in Figure 2. Secondly, the project team divided all counties (cities and

districts) into 5 groups according to the per capita GDP level and randomly selected 1 county (city and district) from each group while taking into account the geographical spatial distribution of counties, that is, 5 counties (cities and districts) from each sample province. Thirdly, according to the sampling method similar to the sample counties (cities and districts), 3 townships were randomly selected from each county (cities and districts), and then the administrative villages in each township were divided into two groups of "good" and "poor" according to the economic development and 1 village was randomly selected from each group. Finally, the researcher randomly selected 12–14 households from the roster of administrative village households by using the isometric sampling method and carried out a field investigation according to the questionnaire content. This survey adopts a multi-stage, stratified, and random sampling method, fully considering the regional distribution, economic development level, and social characteristics of rural China, and therefore has high representativeness. Meanwhile, as the sampling process covers farmers from different regions and economic development levels, the survey results have certain generalizability among a wider rural population in China.

Figure 2. Distribution Map of Sample Provinces.

This article focuses on the relationship between farmers' digital literacy and farmers' e-commerce willingness and behavior deviation, deals with relevant farmers' digital literacy, farmers' e-commerce willingness and behavior deviation, and related variables, and deals with missing values and outliers.

In fact, the deviation between willingness and behavior has two meanings. Firstly, expressing a willingness to participate in e-commerce sales but not actually participating in e-commerce sales. Secondly, expressing an unwillingness to participate in e-commerce sales but actually participating in e-commerce sales. However, the probability of the second meaning appearing is extremely small, and willingness is the precursor of behavior. The research value of the special situation represented by the second meaning is limited; this study only focuses on the analysis of the first layer.

Since this article mainly focuses on the conversion problem from willingness to behavior in farmers' e-commerce sales, that is, how farmers can transform from "having intention without action" to "having intention with action", the article defines the deviation between farmers' e-commerce sales willingness and behavior as "farmers having e-commerce sales

willingness but not taking actual action". Since only the deviation situation of farmers with willingness but without action in e-commerce sales is studied, the farmers' samples without e-commerce sales willingness are excluded, the fixed effects of provinces are controlled, and finally, 804 farmers' baseline regression samples are obtained.

3.2. Variable Design and Descriptive Statistics

3.2.1. Dependent Variable

The dependent variable in this paper is the deviation between farmers' e-commerce sales willingness and behavior, which is measured by the index of "farmers have e-commerce sales willingness but have not taken actual actions". If this is the case, the variable is assigned as 1, otherwise it is 0.

3.2.2. Key Independent Variable

The key independent variable in this study is farmers' digital literacy, which is measured across five dimensions: media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognition literacy, and digital social literacy. As previously mentioned, media operation literacy refers to the ability of farmers to use digital media, measured by whether farmers use digital media, the level of difficulty in using digital media, and whether they have received training for internet use on computers or mobile phones. Information acquisition literacy refers to farmers' ability to access information through digital media for their daily needs, measured by whether farmers can access information through digital media and whether the information obtained through digital media meets their daily needs. Digital transaction literacy refers to farmers' ability to conduct transactions through digital media, measured by whether they have made online payments for services and their preference for digital payments. E-commerce cognition literacy refers to farmers' level of awareness of e-commerce, measured by whether they have received training or guidance on e-commerce. Digital social literacy refers to the potential of farmers to disseminate information through new media social channels, measured by whether farmers use platforms such as WeChat, live streaming, and short videos. This study selected eleven specific items through a survey questionnaire and used factor analysis to obtain a comprehensive score for digital literacy. The sample was assessed using the Kaiser-Meyer-Olkin (KMO) measure and Bartlett's sphericity test. The KMO value was greater than 0.7, and the p-value of Bartlett's test was 0.000, indicating that the sample data was suitable for factor analysis and that using factor analysis to construct the scoring model was appropriate. The specific items and test results are shown in Table 1.

Table 1. Measurement of the digital literacy variable.

Variable	Index	Measurement Item	KMO	Bartlett *p*-Value
Digital literacy	Media operation literacy	Do you use a 4G/5G phone	0.703	0.000
		Have you mastered the functions of using 4G/5G phones		
		Have you received any training on computer or mobile internet access		
	Information acquisition literacy	Can you access relevant information at any time via mobile phone or Internet		
		Do you think the information obtained through the internet can meet daily needs such as production and life		

Table 1. *Cont.*

Variable	Index	Measurement Item	KMO	Bartlett *p*-Value
Digital literacy	Digital transaction literacy	Have you ever paid for a mobile APP service	0.703	0.000
		Is digital payment the preferred payment method for purchasing agricultural inputs such as seedlings, fertilizers, and feed in your home		
		If your family wants to purchase or has recently purchased vehicles (sedans, agricultural vehicles, etc.), is the preferred payment method digital payment		
	E-commerce cognition literacy	Have you received e-commerce training or guidance		
	Digital social literacy	Do you use digital social platforms such as WeChat		
		Do you use live streaming or other digital applications for entertainment		

3.2.3. Mediating Variable

The mediating variables in this study are financial access and agricultural production service access. The financial access variable is characterized by "whether your household has applied for a loan from a formal bank (including rural credit cooperatives, and township banks)" and "whether the loan was approved by the bank". The agricultural production service access is represented by "whether they adopt fertilization services", "whether they purchase mechanized fertilization services", "whether they receive fertilization services from cooperatives", and "the time when the services are provided".

3.2.4. Control Variable

This article selects control variables based on research questions and existing literature experience in terms of personal and family characteristics [13,29,30,69]. Farmer participation in e-commerce behavior belongs to personal behavior, so the selection of control variables should try to summarize important personal traits. At the same time, participation in e-commerce is closely related to family capital endowments. Based on the availability of survey questionnaire data, the control variables for respondents include age, age squared, gender, education level, cadre status, agricultural labor time, part-time employment, household annual income, land scale, and social capital. In order to reduce heteroscedasticity and approximate a normal distribution, the natural logarithm was applied to the household annual income variable.

3.2.5. Instrumental Variable

In order to address the potential endogeneity issues arising from measurement errors, reverse causal relationships, or omitted variables in the study of the impact of digital literacy on the willingness and behavior of farmers to sell e-commerce, this study introduces instrumental variables to address the issue and selects "average level of digital literacy among surveyed farmers in the same village" as the instrumental variable. Based on the theory of peer effects [70,71], individuals are not only influenced by their own characteristics but also by other individuals within the group, especially in rural China, where farmers have frequent interactions and close relationships [72], and their mastery of digital technology is influenced by other individuals. The average level of digital literacy among farmers in the same village reflects the local level of digitalization, which is related to the individual digital literacy of farmers. Based on this, the average level of digital literacy among farmers in the same village meets the correlation requirements of instrumental variables. Secondly, based on the experience of existing literature [73], the average level of digital literacy among farmers in the same village belongs to the village level variable,

which is different from the observation level of individual e-commerce behavior. It will not directly affect the behavioral choices of farmers in e-commerce, meeting the exogenous requirements of instrumental variables. In summary, selecting this instrumental variable is reasonable. The specific variables and descriptive statistics are presented in Table 2.

Table 2. Descriptive statistics of variables.

Variable Type	Variable Definition	Variable Description and Assignment	Mean Value	Standard Deviation
Dependent variable	Deviation between farmers' e-commerce sales willingness and behavior	Yes = 1, No = 0	0.771	0.420
Independent variable	Digital literacy	Overall digital literacy score	7.33×10^{-10}	0.580
Mediating variable	Financial access	Have you ever applied for a loan from a regular bank Yes = 1, no = 0	0.321	0.467
		Whether the bank approves the loan? Yes = 1, no = 0	0.306	0.461
	Agricultural production service access	Whether to accept fertilization service Yes = 1, no = 0	0.160	0.367
		Service investment time (man-hour)	1.841	7.855
		Whether to adopt mechanized service Yes = 1, no = 0	0.071	0.258
		Whether to adopt cooperative service Yes = 1, no = 0	0.005	0.073
Control variable	Age	Age (years)	50.409	10.802
	Age^2	Age squared term/100	26.576	10.784
	Gender	Male = 1; Female = 0	0.794	0.405
	Education	1 = not in school; 2 = primary school; 3 = junior high school; 4 = high school; 5 = technical secondary school; 6 = vocational high school; 7 = college degree; 8 = undergraduate degree; 9 = Graduate student	3.150	1.252
	Cadre	Do you have a position in this village? Yes = 1, No = 0	0.252	0.435
	Agricultural labor time	Farm labor time of household in one year (days)	135.086	119.100
	By-business	By-business, yes = 1, no = 0	0.269	0.444
	Annual household income	Take the logarithm of annual household income	11.033	1.113
	Land scale	Total operating land area	38.869	122.213
	Social capital	How many relatives and friends do you have who can borrow money (more than 5000 CNY)	8.248	8.367
Instrumental variable	Average digital literacy of village farmers	The average comprehensive score of digital literacy among surveyed farmers in villages	−0.001	0.383

3.3. Model

3.3.1. Probit Model

The dependent variable is the deviation between farmers' e-commerce sales willingness and behavior, and the value is 0 or 1, which is a discrete variable. It is more appropriate to consider adopting the probit model. Therefore, in order to investigate the impact of

farmers' digital literacy on the deviation between e-commerce willingness and behavior, the following probit model was set up in this paper for benchmark regression:

$$Prob(Y_i = 1) = \beta_0 + \beta_1 D_i + \beta_2 Z_i + \varepsilon_i \tag{1}$$

Among them, Y_i is whether there is a deviation between the willingness to participate in e-commerce and the behavior of the i farmer, D_i represents the relevant variable of the i farmer's digital literacy, and Z_i represents the set of control variables. The control variables include the respondent's age, age squared, gender, education level, cadre status, health status, agricultural labor time, by-business, household annual income, land scale, and social capital. ε_i represents random disturbance.

3.3.2. Endogenous Transformation Probit Model

The endogenous transformation probit model can solve the problem of sample selection bias caused by observable and unobservable variables [74,75]. Taking into account the selection bias and heterogeneity factors of sample farmers, this article uses the probit model for benchmark regression and instrumental variable correction to address endogeneity issues that may arise due to measurement errors, reverse causality, or omitted variables. Based on the regression results, a "counterfactual" analysis framework is constructed using the endogenous transformation probit model to correct endogeneity issues, Estimate the average processing effect of digital literacy on the probability of deviation between the willingness and behavior of farmers in e-commerce sales.

Firstly, the digital literacy measured by multidimensional indicators (media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognition literacy, and digital social literacy) will be used as processing variables (D_i). This article uses "whether one has mastered the functions of 4G/5G phones" as a proxy variable for media operation literacy; "whether information can be obtained at any time through mobile phones or the internet" as a proxy variable for information acquisition literacy; "whether payment has been made for mobile services" as the proxy variable for digital transactions; "whether one has received e-commerce training or guidance" as a proxy variable for e-commerce cognition literacy; and "whether to use digital platforms such as live streaming and video" as a proxy variable for digital social literacy. This facilitates analysis using endogenous transformation models. If farmers have this literacy, then $D_i = 1$, otherwise $D_i = 0$.

The normal distribution function is used to estimate the probability of farmers with digital literacy and the deviation between e-commerce sales willingness and behavior as follows:

$$E(Y_{it}|D_i = 1) = X_{it}\beta_t + \sigma_{\mu t}\lambda_t \tag{2}$$

The probability that farmers have digital literacy and e-commerce sales willingness and behavior are consistent is as follows:

$$E(Y_{iu}|D_i = 1) = X_{it}\beta_u + \sigma_{\mu u}\lambda_t \tag{3}$$

Among them, Y_{it} and Y_{iu} represent the deviation between e-commerce sales willingness and behavior of farmers with and without digital literacy, X_{it} represents the factors affecting the deviation between e-commerce sales willingness and behavior of farmers with digital literacy, and β_t and β_u represent the parameters to be estimated.

By comparing (2) and (3), the average processing effect of e-commerce sales willingness and behavior deviation of digitally literate farmers is as follows:

$$\text{ATT} = E(Y_{it}|D_i = 1) - E(Y_{iu}|D_i = 1) = X_{it}(\beta_t - \beta_u) + (\sigma_{\mu t} - \sigma_{\mu u})\lambda_t \tag{4}$$

4. Results and Discussion

4.1. Benchmark Regression

Table 3 reports the results of the baseline regression using the probit model. Models (1) to (5) include control variables and control for provincial fixed effects. Model (1) examines the impact of digital literacy on the deviation of farmers' e-commerce sales intentions and behaviors. Models (2) to (5) explore the effects of media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy on the deviation of farmers' e-commerce sales intentions and behaviors. The results indicate that digital literacy has a significant negative impact on the deviation of farmers' e-commerce sales intentions and behaviors at a 1% significance level, with an estimated coefficient of −0.616. Additionally, media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy all have significant negative effects on the deviation of farmers' e-commerce sales intentions and behaviors, with estimated coefficients of −0.241, −0.232, −0.147, −0.402, and −0.118, respectively. This confirms Hypothesis 1. These findings suggest that digital literacy mitigates the deviation of farmers' e-commerce sales intentions and behaviors, and farmers with higher digital literacy are more likely to translate e-commerce intentions into actions. It is particularly important to enable farmers to truly enjoy the dividends of the digital economy, extend e-commerce benefits to more farmers, improve their digital literacy level, and bridge the digital divide.

Table 3. Benchmark regression results.

	Deviation between Farmers' E-Commerce Sales Willingness and Behavior					
	(1)	(2)	(3)	(4)	(5)	(6)
Digital literacy	−0.616 *** (0.136)					
Media operation literacy		−0.241 *** (0.077)				
Information acquisition literacy			−0.232 ** (0.092)			
Digital transaction literacy				−0.147 *** (0.055)		
E-commerce cognition literacy					−0.402 *** (0.128)	
Digital social literacy						−0.118 ** (0.056)
Age	0.018 (0.036)	0.005 (0.034)	0.005 (0.035)	0.005 (0.035)	−0.005 (0.034)	−0.009 (0.034)
Age squared	−0.024 (0.037)	−0.007 (0.035)	−0.004 (0.036)	−0.004 (0.036)	0.011 (0.034)	0.012 (0.034)
Gender	−0.035 (0.135)	−0.021 (0.133)	0.004 (0.133)	0.017 (0.132)	−0.030 (0.134)	−0.037 (0.132)
Education level	−0.011 (0.044)	−0.029 (0.043)	−0.044 (0.044)	−0.050 (0.043)	−0.053 (0.043)	−0.069 (0.043)
Cadre	0.087 (0.123)	0.062 (0.119)	0.060 (0.121)	0.047 (0.121)	0.097 (0.121)	0.006 (0.119)
Agricultural labor hours	0.001 (0.000)	0.001 (0.000)	0.001 * (0.000)	0.001 * (0.000)	0.001 (0.000)	0.001 * (0.000)
By-business	−0.056 (0.120)	−0.093 (0.116)	−0.127 (0.118)	−0.121 (0.117)	−0.086 (0.117)	−0.128 (0.115)
Annual household income	−0.146 ** (0.057)	−0.186 *** (0.055)	−0.181 *** (0.055)	−0.175 *** (0.056)	−0.198 *** (0.055)	−0.200 *** (0.055)
Total operating land area	−0.001 * (0.001)	−0.001 (0.000)	−0.001 * (0.001)	−0.001 ** (0.001)	−0.001 (0.000)	−0.001 (0.000)

Table 3. *Cont.*

	Deviation between Farmers' E-Commerce Sales Willingness and Behavior					
	(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
Social capital	0.009	0.006	0.005	0.004	0.008	0.005
	(0.007)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Provincial fixed effects	YES	YES	YES	YES	YES	YES
_cons	2.407 **	3.152 ***	3.050 ***	2.980 ***	3.389 ***	3.699 ***
	(1.048)	(0.993)	(1.022)	(1.030)	(0.995)	(0.984)
N	804	847	812	823	841	847
Pseudo R-squared	0.109	0.095	0.092	0.090	0.091	0.086

Standard errors in parentheses, * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$; the same applies to the subsequent tables.

Song et al. (2023) [30] showed that the overall effect of Internet use on farmers' adoption of online sales was 0.133 and significant and concluded that information literacy such as information needs and information application promoted farmers' use of the Internet for sales at an impact level of 0.112, 0.009, while this study analyzed the overall effect of digital literacy on farmers' e-commerce sales willingness and behavior deviation as −0.616, which is significant at 1% statistical level, and this paper provides a new analytical perspective for understanding farmers' e-commerce sales adoption behavior at the level of digital literacy.

The results of the controlling variables show that the annual income and land size of rural households have a significant negative impact on the discrepancy between their willingness and behavior in e-commerce sales. Farmers with higher annual household income have stronger financial investment capabilities, which can optimize the e-commerce supply chain and marketing processes, thereby increasing their enthusiasm to participate in e-commerce sales. Farmers with abundant land resources usually have more productivity and a greater supply of agricultural products, which can easily form economies of scale. This gives them greater business potential in e-commerce sales, which encourages farmers to adopt e-commerce sales. The positive impact of household annual income and land management scale on e-commerce sales is consistent with existing research findings [13].

4.2. Endogenous Processing

In the benchmark model, the impact of digital literacy on the discrepancy between the willingness and behavior of farmers to sell e-commerce may still have potential endogeneity issues due to measurement errors, reverse causality, or omitted variables. Based on this, this article introduces an instrumental variable (the average digital literacy of village farmers) for correction, and the instrumental variable method divides the explanatory variables with endogeneity problems into two parts through instrumental variables: the exogenous part and the endogenous part. In the first stage, the instrumental variable is used as the independent variable, and the original endogenous explanatory variable is used as the dependent variable for regression to obtain the fitted value of the endogenous explanatory variable. In the second stage, the dependent variable is used to regress the fitted value obtained in the first stage of regression to achieve the purpose of correcting the endogenous explanatory variable [76].

Due to the fact that the dependent variable in this study is a binary variable and IV probit is suitable for this situation, the IV probit method was used for regression. Table 4 shows the two-stage regression results of the IV probit method. In stage one, the coefficient of the instrumental variable is significant at the 1% statistical level, and the *p*-values of the AR test and Wald test are both less than 0.05, indicating the absence of a weak instrumental variable phenomenon. The results showed that, after addressing potential endogeneity issues, digital literacy still significantly suppressed the discrepancy between farmers' willingness and behavior in e-commerce sales, further validating Hypothesis 1.

Table 4. Analysis results of instrumental variables.

Variable	Deviation between Farmers' E-Commerce Sales Willingness and Behavior	
	Phase 2	Phase 1
Digital literacy	−0.525 ** (0.238)	
Instrumental variable (IV)		0.744 *** (0.042)
Control variable	YES	YES
Provincial fixed effects	YES	YES
AR test *p*-value	0.029	
Wald test *p*-value	0.028	
Observations	804	804

** $p < 0.05$, *** $p < 0.01$.

This article further uses the endogenous transformation probit model to analyze the multidimensional indicators of digital literacy (media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy) in order to further address potential endogeneity issues. Table 5 shows the average processing effects of media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy on the deviation of farmers' e-commerce sales willingness and behavior. The results showed that the estimated ATT values for media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy were −0.123, −0.183, −0.262, −0.375, and −0.219, respectively, which were significant at the 1% statistical level. The meaning was that 494 farmers with media operation literacy reduced the probability of e-commerce sales intention and behavior deviation by 12.3% compared to those without media operation literacy (counterfactual); 733 farmers with information acquisition literacy had a 18.3% reduction in the probability of e-commerce sales intention and behavior deviating compared to those without information acquisition literacy (counterfactual); 178 farmers with digital trading literacy had a 26.2% reduction in the probability of e-commerce sales intention and behavior deviating compared to those without digital trading literacy (counterfactual); 149 farmers with e-commerce cognitive literacy had a 37.5% lower probability of deviating from their e-commerce sales intentions and behaviors compared to those without e-commerce cognitive literacy (counterfactual); 383 farmers with digital social literacy had a 21.9% reduction in the probability of e-commerce sales intention and behavior deviation compared to those without digital social literacy (counterfactual). Hypothesis 1 of this article has been validated again.

Table 5. The average processing effect of digital literacy on the deviation between e-commerce sales willingness and behavior.

	Observations	ATT	Standard Error	t-Value
Media operation literacy	494	−0.123 ***	0.003	−44.541
Information acquisition literacy	733	−0.183 ***	0.006	−28.839
Digital transaction literacy	178	−0.262 ***	0.009	−28.754
E-commerce cognition literacy	149	−0.375 ***	0.012	−31.169
Digital social literacy	383	−0.219 ***	0.005	−48.485

*** $p < 0.01$.

4.3. Robustness Test

To test the robustness of the above results again, this article adopts the method of replacing samples for robustness testing, and the results are shown in Table 6. We selected a sample of farmers engaged in the forestry and fruit industries for regression, and the results are shown in Model (1). The symbols and significance of the core independent

variable, digital literacy, are consistent with the results of the benchmark regression model. Then, we selected a sample of farmers engaged in the planting industry for regression, and the results are shown in Model (2), which is still robust.

Table 6. Robustness test results.

	(1)	(2)
Digital literacy	−0.790 ***	−0.733 ***
	(0.189)	(0.213)
Control variable	YES	YES
Provincial fixed effects	YES	YES
_cons	1.563	3.768
	(2.057)	(1.480)
N	259	526
Pseudo R-squared	0.132	0.179

*** $p < 0.01$.

4.4. Impact Mechanism Testing

Table 7 presents the analysis results of the impact mechanism of financial acquisition. Financial acquisition is measured by whether farmers have applied for loans from formal banks (including rural credit cooperatives and rural banks) and whether they have obtained bank approval.

Table 7. Analysis results of the impact mechanism of financial acquisition.

	(1)	(2)
	Financial Access	**Financial Approval Obtained**
Digital literacy	0.283 ***	0.256 **
	(0.109)	(0.111)
Control variable	YES	YES
Provincial fixed effects	YES	YES
_cons	−1.928 **	−2.223 **
	(0.980)	(1.001)
N	803	804
Pseudo R-squared	0.112	0.115

** $p < 0.05$, *** $p < 0.01$.

Model (1) shows the impact of digital literacy on farmers applying for loans from formal banks, with an estimated coefficient significantly positive at the 1% level. Model (2) shows the impact of digital literacy on farmers obtaining bank approval for loan applications, with an estimated coefficient significantly positive at the 5% level. The above results demonstrate from the perspectives of the enthusiasm and success rate of financial acquisition by farmers that digital literacy promotes their financial acquisition, thus testing that digital literacy suppresses the contradiction between e-commerce sales willingness and behavior through financial acquisition by farmers. Hypothesis 2 is validated. Anna (2022) found that both digital literacy and financial literacy are determining factors for individuals to access finance [34]. This study empirically confirms the positive impact of digital literacy on farmers' financial access, which is consistent with existing research findings.

Table 8 presents the analysis results of the impact mechanism on the acquisition of agricultural production services. Taking the application of chemical fertilizers as an example to discuss agricultural production services. This study measures agricultural production service acquisition from four aspects: whether farmers adopt fertilizer application services, service provision time, whether they adopt mechanized services, and cooperative services.

Table 8. Analysis results of the impact mechanism on the acquisition of agricultural production services.

	(1)	(2)	(3)	(4)
	Service	Service Investment Time	Mechanical Service	Cooperative Service
Digital literacy	0.474 **	0.729 ***	0.315 *	1.178 ***
	(0.207)	(0.257)	(0.174)	(0.240)
Control variable	YES	YES	YES	YES
Provincial fixed effects	YES	YES	YES	YES
_cons	3.345 *	5.434 ***	3.500 **	5.014
	(1.800)	(2.066)	(1.572)	(5.340)
N	323	225	580	152
Pseudo R-squared (R-squared)	0.167	0.155	0.164	0.193

* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Model (1) shows the impact of digital literacy on the adoption of fertilizer application services, with an estimated coefficient significantly positive at the 5% level. Model (2) shows the impact of digital literacy on service delivery time, with an estimated coefficient significantly positive at the 1% level. Model (3) shows the impact of digital literacy on the adoption of mechanized services, with an estimated coefficient significantly positive at the 10% level. Model (4) shows the impact of digital literacy on cooperative service adoption, with an estimated coefficient significantly positive at the 1% level. The above results demonstrate that digital literacy promotes the acquisition of agricultural production services by farmers from two perspectives: the adoption of production services and the time of service investment. This verifies that digital literacy suppresses the paradox between e-commerce sales willingness and behavior through the acquisition of agricultural production services by farmers. Hypothesis 3 has been validated. Yang et al. (2023) found that internet use has a positive impact on the adoption of agricultural production services [37], and the effectiveness of internet use is related to digital literacy. This article confirms the positive impact of digital literacy on the adoption of agricultural production services by farmers, filling a gap in existing research.

4.5. Heterogeneity Analysis

From the benchmark regression results, it can be seen that the scale of land management has a significant negative impact on the discrepancy between the willingness and behavior of farmers to sell e-commerce. This article further divides farmers into groups based on the median of the total land management area (8) and conducts group regression to explore whether the impact of digital literacy on e-commerce sales has heterogeneity in the land management scale. Table 9 presents the results of the heterogeneity analysis of land scale among farmers. The results show that the absolute value of the estimated coefficient of digital literacy on the "Large land scale" is much higher than that on the "Small land scale", and the empirical p-value is less than 0.1, indicating that the coefficients of group regression are comparable. This indicates that, compared to farmers with smaller land scales, farmers with larger land scales have a more significant inhibitory effect of digital literacy on the discrepancy between e-commerce sales willingness and behavior. Farmers have a large amount of land resources, which can easily form economies of scale, enabling them to obtain higher profits from e-commerce sales in the future. This stimulates the enthusiasm of farmers to transform their willingness to sell e-commerce into behavior.

Table 9. Analysis results of heterogeneity in land management scale.

Variable	(1) Smaller Land Scale	(2) Larger Land Scale
Digital literacy	−0.513 ***	−0.956 ***
	(0.179)	(0.190)
Control variable	YES	YES
Provincial fixed effects	YES	YES
_cons	0.769	3.253 *
	(1.525)	(1.773)
Empirical *p*-value	0.080	
N	409	383
Pseudo R-squared	0.099	0.188

* $p < 0.1$, *** $p < 0.01$.

5. Conclusions

This study uses the data from the 2020 "China Rural Revitalization survey" to empirically analyze the impact of digital literacy on Farmers' e-commerce sales willingness and behavior deviation from the micro perspective of farmers and draws some important conclusions. It answers the research question raised in this paper, that is, whether digital literacy will inhibit farmers' e-commerce sales willingness and behavior deviation, what is the impact mechanism, and makes up for the blanks of the current research. The empirical results show that digital literacy can inhibit the deviation between farmers' e-commerce sales willingness and behavior. By cultivating farmers' digital literacy and improving their ability to access and utilize information, farmers can easily access e-commerce market information to plan agricultural production. Through digital technology, farmers can achieve intelligent and informative management of the agricultural production process, including soil testing, weather monitoring, and precise fertilizer application. This not only improves the yield and quality of agricultural products but also helps to reduce resource wastage and environmental pollution and promote sustainable agricultural development.

This study deeply analyzes the connotation of digital literacy. Based on the actual needs of farmers in the digital environment and the application scenario of e-commerce participation, and relying on the data from the 2020 "China Rural Revitalization survey", it selects eleven index items and constructs five dimensions of digital literacy: media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy. Through the probit model regression analysis, it was found that they all inhibit the contradiction between farmers' e-commerce sales willingness and behavior. Therefore, to suppress the contradiction between farmers' e-commerce sales willingness and behavior, we need to improve farmers' digital literacy in the aspects of media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy. This study helps to understand what kind of digital skills farmers need to master and provides references for relevant units to formulate more detailed training content so as to better deal with the challenges brought by the digital economy to farmers.

In terms of research methods, the study also used the IV-probit method and the endogenous switching probit model to address potential endogeneity issues. Based on the analysis of the endogenous switching probit model, farmers with media operation literacy, information acquisition literacy, digital transaction literacy, e-commerce cognitive literacy, and digital social literacy had reduced the probability of deviation in their e-commerce sales willingness and behavior by 12.3%, 18.3%, 26.2%, 37.5%, and 21.9%, respectively, compared to the counterfactual assumption that they did not possess these literacies.

In addition, the study further analyzed the mechanism by which digital literacy affects the deviation of farmers' e-commerce sales willingness and behavior, filling in the gaps in current research. It was found that digital literacy inhibits the deviation of farmers' e-commerce sales willingness and behavior by promoting mechanisms for farmers to ob-

tain financial and agricultural production services. Specifically, digital literacy positively influenced farmers' applications for loans from formal banks (including rural credit cooperatives and township banks) and obtaining bank approval; digital literacy also had a positive impact on farmers' access to agricultural production services, with significant positive effects on adopting cooperative services, mechanization services, and service input time. The results illustrate that improving the accessibility of financial and agricultural production services is crucial to promoting farmers' participation in e-commerce, addressing the issues of insufficient funding, technology, and labor faced by farmers participating in e-commerce. Agricultural production services and financial services address the technical and economic scale constraints of farmers to improve the quality of agricultural products, bring farmers the cost advantage of adopting green and sustainable production, drive the production of sustainable agricultural products, promote products through e-commerce, and promote economic growth and sustainable development. In terms of heterogeneity analysis, the inhibitory impact of digital literacy on the deviation of e-commerce sales willingness and behavior was more significant for farmers with relatively abundant land resources, and farmers with a certain endowment of land resources were more likely to engage in e-commerce activities and potentially obtain higher returns. To sum up, Hypothesis 1, Hypothesis 2, and Hypothesis 3 proposed in this study have been confirmed.

Based on the above conclusions, this article proposes the following policy recommendations:

1. Improving the digital literacy of farmers: Improving the digital literacy of farmers requires both government leadership and the power of all sectors of society. Firstly, improve rural digital infrastructure, increase network coverage, and enable farmers to enjoy the convenience of network usage. Secondly, strengthening the training of digital skills for farmers and improving their awareness and application ability of digital technology will help farmers better understand and utilize e-commerce platforms and alleviate the problem of information asymmetry. Cultivate a group of "new farmers" who are adapted to the digital economy, drive local farmers to participate in digital activities such as e-commerce live streaming and short video shooting, and improve the enthusiasm of farmers to participate in digital life.

2. Actively provide financial support: Encourage financial institutions to actively carry out digital finance and provide flexible loan and financing options for farmers. Guide financial institutions to invest in the development of rural e-commerce. Provide special funds for poverty alleviation, small loans for poverty alleviation, and interest subsidies for poverty alleviation to alleviate the economic pressure brought by farmers participating in e-commerce projects.

3. Promote agricultural socialized services: Promote the development of agricultural socialized services and provide relevant technical support and training for farmers. By receiving production services from professional organizations, farmers can reduce their business burden, improve the yield and quality of their agricultural products, and promote the production of green and sustainable agricultural products so that they have more time and energy to participate in e-commerce sales and have better quality products to participate in e-commerce sales.

4. Optimizing resource management: Helping farmers effectively manage their land resources and labor can promote their participation in e-commerce. Government consulting services can play a crucial role in effectively allocating resources.

Finally, this article also has some limitations. Firstly, due to data limitations, this article can only conduct cross-sectional analysis and cannot observe long-term effects and dynamic changes. Future research can collect panel data to observe changes in farmer behavior over time. Secondly, future research can focus more on the impact mechanism of digital literacy on promoting rural e-commerce sales. Due to data limitations, this study focuses on the mechanisms of financial access and agricultural production service access, but there are still other impact mechanisms that can be further analyzed.

References

1. Rehman, N.U.; Nunziante, G. The effect of the digital economy on total factor productivity in European regions. *Telecommun. Policy* **2023**, *47*, 102650. [CrossRef]
2. Zhu, F.; Shi, Q.; Balezentis, T.; Zhang, C. The impact of e-commerce and R & D on firm-level production in China: Evidence from manufacturing sector. *Struct. Chang. Econ. D* **2023**, *65*, 101–110. [CrossRef]
3. Alam, S.S.; Masukujjaman, M.; Makhbul, Z.K.M.; Ali, M.H.; Omar, N.A.; Siddik, A.B. Impulsive hotel consumption intention in live streaming E-commerce settings: Moderating role of impulsive consumption tendency using two-stage SEM. *Int. J. Hosp. Manag.* **2023**, *115*, 103606. [CrossRef]
4. Altarturi, H.H.M.; Nor, A.R.M.; Jaafar, N.I.; Anuar, N.B. A bibliometric and content analysis of technological advancement applications in agricultural e-commerce. *Electron. Commer. Res.* **2023**, 1–44. [CrossRef]
5. Lin, J.; Li, H.; Lin, M.; Li, C. Rural e-commerce in China: Spatial dynamics of Taobao Villages development in Zhejiang Province. *Growth Chang.* **2022**, *53*, 1082–1101. [CrossRef]
6. Yang, R. Space reconstruction process and internal driving mechanisms of Taobao villages in metropolitan fringe areas: A case study of Lirendong village in Guangzhou, China. *J. Geogr. Sci.* **2022**, *32*, 2599–2623. [CrossRef]
7. Li, X.; Guo, H.; Jin, S.; Ma, W.; Zeng, Y. Do farmers gain internet dividends from E-commerce adoption? Evidence from China. *Food Policy* **2021**, *101*, 102024. [CrossRef]
8. Yang, C.; Ji, X.; Cheng, C.; Liao, S.; Obuobi, B.; Zhang, Y. Digital economy empowers sustainable agriculture: Implications for farmers, adoption of ecological agricultural technologies. *Ecol. Indic.* **2024**, *159*, 111723. [CrossRef]
9. Zhang, Y.C.; Yang, C.; Obuobi, B.; Grant, M.K. Entrepreneurial opportunity, value evolution, and organizational integration of professional farmer entrepreneurship: A multi-case comparison in China. *Front. Agric. Sci. Eng.* **2022**, *10*, 135–148. [CrossRef]
10. Ji, X.; Xu, J.; Zhang, H. Environmental effects of rural e-commerce: A case study of chemical fertilizer reduction in China. *J. Environ. Manag.* **2022**, *326*, 116713. [CrossRef]
11. Wang, H.; Fang, L.; Mao, H.; Chen, S. Can e-commerce alleviate agricultural non-point source pollution?—A quasi-natural experiment based on a China's E-Commerce Demonstration City. *Sci. Total Environ.* **2022**, *846*, 157423. [CrossRef]
12. Li, B.; Xu, C.; Zhu, Z.; Kong, F. Does e-commerce drive rural households engaged in non-timber forest product operations to adopt green production behaviors? *J. Clean. Prod.* **2021**, *320*, 128855. [CrossRef]
13. Liu, M.; Min, S.; Ma, W.; Liu, T. The adoption and impact of E-commerce in rural China: Application of an endogenous switching regression model. *J. Rural. Stud.* **2021**, *83*, 106–116. [CrossRef]
14. Wei, X.; Ruan, J. Influences of Government Policies and Farmers' Cognition on Farmers' Participation Willingness and Behaviors in E-Commerce Interest Linkage Mechanisms during Farmer-Enterprise Games. *Agriculture* **2022**, *12*, 1625. [CrossRef]
15. Li, X.; Sarkar, A.; Xia, X.; Memon, W.H. Village Environment, Capital Endowment, and Farmers' Participation in E-Commerce Sales Behavior: A Demand Observable Bivariate Probit Model Approach. *Agriculture* **2021**, *11*, 868. [CrossRef]
16. Funta, R.; Buttler, D. The digital economy and legal challenges. *InterEULawEast* **2023**, *10*, 145–160. [CrossRef]
17. Peráček, T. E-commerce and its limits in the context of consumer protection: The case of the Slovak Republic. *Jurid. Trib.* **2022**, *12*, 35–50. [CrossRef]
18. Aliaj, E.; Tiri, E. E-commerce regulation in Albania. *Jurid. Trib.* **2023**, *13*, 443–455. [CrossRef]
19. Orzoł, M.; Szopik-Depczyńska, K. E-commerce and the development of communication infrastructure in Poland. *Procedia Comput. Sci.* **2022**, *207*, 3957–3968. [CrossRef]

20. Leroux, N.; Wortman, M.S.; Mathias, E.D. Dominant factors impacting the development of business-to-business (B2B) e-commerce in agriculture. *Int. Food Agribus. Manag. Rev.* **2001**, *4*, 205–218. [CrossRef]
21. Qi, J.; Zheng, X.; Guo, H. The formation of Taobao villages in China. *China Econ. Rev.* **2019**, *53*, 106–127. [CrossRef]
22. Kshetri, N. Barriers to e-commerce and competitive business models in developing countries: A case study. *Electron. Commer. Res. Appl.* **2007**, *6*, 443–452. [CrossRef]
23. Hendricks, S.; Mwapwele, S.D. A systematic literature review on the factors influencing e-commerce adoption in developing countries. *Data Inf. Manag.* **2023**, *8*, 100045. [CrossRef]
24. Goncalves, G.; Oliveira, T.; Cruz-Jesus, F. Understanding individual-level digital divide: Evidence of an African country. *Comput. Hum. Behav.* **2018**, *87*, 276–291. [CrossRef]
25. ESHET-ALKALAI, Y. Digital Literacy: A Conceptual Framework for Survival Skills in the Digital Era. *J. Educ. Multimed. Hypermedia* **2004**, *13*, 93–106.
26. Hargittai, E. Survey measures of web-oriented digital literacy. *Soc. Sci. Comput. Rev.* **2005**, *23*, 371–379. [CrossRef]
27. Ali, A.; Raza, A.A.; Qazi, I.A. Validated digital literacy measures for populations with low levels of internet experiences. *Dev. Eng.* **2023**, *8*, 100107. [CrossRef]
28. Nichols, T.P.; Stornaiuolo, A. Assembling "Digital Literacies": Contingent Pasts, Possible Futures. *Media Commun.-Lisbon.* **2019**, *7*, 14–24. [CrossRef]
29. Ma, W.; Zhou, X.; Liu, M. What drives farmers' willingness to adopt e-commerce in rural China? The role of Internet use. *Agribusiness* **2020**, *36*, 159–163. [CrossRef]
30. Song, C.; Zheng, S.; Zhang, Q.; Wei, J.; Chen, Y.; Irfan, M. Can fiscal decentralization and farmers' use of internent be the route to the digitalization performance in China? A novel approach towards unlocking the role of online marketing behavior and performance of agricultural products. *Environ. Sci. Pollut. Res.* **2023**, *30*, 87382–87397. [CrossRef]
31. Ariansyah, K.; Sirait, E.R.E.; Nugroho, B.A.; Suryanegara, M. Drivers of and barriers to e-commerce adoption in Indonesia: Individuals' perspectives and the implications. *Telecommun. Policy* **2021**, *45*, 102219. [CrossRef]
32. Zhong, Z.; Jiang, W.; Li, Y. Bridging the gap between smallholders and modern agriculture: Full insight into China's agricultural cooperatives. *J. Rural. Stud.* **2023**, *101*, 103037. [CrossRef]
33. Zou, Q.; Zhang, Z.; Yi, X.; Yin, C. The direction of promoting smallholders' adoption of agricultural green production technologies in China. *J. Clean. Prod.* **2023**, *415*, 137734. [CrossRef]
34. Lo Prete, A. Digital and financial literacy as determinants of digital payments and personal finance. *Econ. Lett.* **2022**, *213*, 110378. [CrossRef]
35. Lei, H.; Su, Q. Does the Use of Digital Finance Affect Household Farmland Transfer-Out? *Sustainability* **2023**, *15*, 2103. [CrossRef]
36. Miine, L.K.; Akorsu, A.D.; Boampong, O.; Bukari, S. Drivers and intensity of adoption of digital agricultural services by smallholder farmers in Ghana. *Heliyon* **2023**, *9*, e23023. [CrossRef] [PubMed]
37. Yang, C.; Cheng, C.; Cheng, N.; Zhang, Y. Research on the Impact of Internet Use on Farmers' Adoption of Agricultural Socialized Services. *Sustainability* **2023**, *15*, 7823. [CrossRef]
38. Li, F.; Zang, D.; Chandio, A.A.; Yang, D.; Jiang, Y. Farmers' adoption of digital technology and agricultural entrepreneurial willingness: Evidence from China. *Technol. Soc.* **2023**, *73*, 102253. [CrossRef]
39. Engas, K.G.; Raja, J.Z.; Neufang, I.F. Decoding technological frames: An exploratory study of access to and meaningful engagement with digital technologies in agriculture. *Technol. Forecast. Soc.* **2023**, *190*, 122405. [CrossRef]
40. Kos, D.; Kloppenburg, S. Digital technologies, hyper-transparency and smallholder farmer inclusion in global value chains. *Curr. Opin. Environ. Sust.* **2019**, *41*, 56–63. [CrossRef]
41. Min, S.; Liu, M.; Huang, J. Does the application of ICTs facilitate rural economic transformation in China? Empirical evidence from the use of smartphones among farmers. *J. Asian. Econ.* **2020**, *70*, 101219. [CrossRef]
42. Zeng, M.; Zheng, Y.; Tian, Y.; Jebbouri, A. Rural E-Commerce Entrepreneurship Education in Higher Education Institutions: Model Construction via Empirical Analysis. *Sustainability* **2022**, *14*, 854. [CrossRef]
43. Gashi, F.; Peci, B. Protection of personal data and privacy in banking sector in kosovo and its impact in consumer protection. *Perspect. L. Public Adm.* **2020**, *9*, 70–78.
44. Wang, Y.; William Feng, D. Identity performance and self-branding in social commerce: A multimodal content analysis of Chinese wanghong women's video-sharing practice on TikTok. *Discourse Context Media* **2022**, *50*, 100652. [CrossRef]
45. Zhang, T.; Tang, Z. Should manufacturers open live streaming shopping channels? *J. Retail. Consum. Serv.* **2023**, *71*, 103229. [CrossRef]
46. Fitriani, N.; Setiawan, D.; Aryani, Y.A.; Arifin, T. Does social media affect performance in e-commerce business? The role of customer management. *J. Open Innov. Technol. Mark. Complex.* **2023**, *9*, 100171. [CrossRef]
47. Wongkitrungrueng, A.; Assarut, N. The role of live streaming in building consumer trust and engagement with social commerce sellers. *J. Bus. Res.* **2020**, *117*, 543–556. [CrossRef]
48. He, Q.; He, J. Analysis of the path to solve the rural financing problem based on "agricultural big Data + Financial Technology". *Optik* **2022**, 170340. [CrossRef]
49. Zscheischler, J.; Brunsch, R.; Rogga, S.; Scholz, R.W. Perceived risks and vulnerabilities of employing digitalization and digital data in agriculture—Socially robust orientations from a transdisciplinary process. *J. Clean. Prod.* **2022**, *358*, 132034. [CrossRef]

50. Agyekumhene, C.; de Vries, J.R.; van Paassen, A.; Macnaghten, P.; Schut, M.; Bregt, A. Digital platforms for smallholder credit access: The mediation of trust for cooperation in maize value chain financing. *NJAS-Wagening. J. Life Sci.* **2018**, *86–87*, 77–88. [CrossRef]
51. Aziz, A.; Naima, U. Rethinking digital financial inclusion: Evidence from Bangladesh. *Technol. Soc.* **2021**, *64*, 101509. [CrossRef]
52. Gao, C.; Wang, Q. Does digital finance aggravate bank competition? Evidence from China. *Res. Int. Bus. Financ.* **2023**, *66*, 102041. [CrossRef]
53. Wang, J. Digital inclusive finance and rural revitalization. *Financ. Res. Lett.* **2023**, *57*, 104157. [CrossRef]
54. Parlasca, M.C.; Johnen, C.; Qaim, M. Use of mobile financial services among farmers in Africa: Insights from Kenya. *Glob. Food Secur.* **2022**, *32*, 100590. [CrossRef]
55. Xu, Y.; Peng, Z.; Sun, Z.; Zhan, H.; Li, S. Does digital finance lessen credit rationing?—Evidence from Chinese farmers. *Res. Int. Bus. Financ.* **2022**, *62*, 101712. [CrossRef]
56. Guo, X.; Wang, L.; Meng, X.; Dong, X.; Gu, L. The impact of digital inclusive finance on farmers' income level: Evidence from China's major grain production regions. *Financ. Res. Lett.* **2023**, *58*, 104531. [CrossRef]
57. Wu, Y.; Duan, X.; Liu, R.; Ma, H.; Zhang, Y. How does full-cost insurance for wheat affect pesticide use? From the perspective of the differentiation of farmers' production scale. *Environ. Res.* **2023**, *242*, 117766. [CrossRef] [PubMed]
58. Dutta, P.; Suryawanshi, P.; Gujarathi, P.; Dutta, A. Managing risk for e-commerce supply chains: An empirical study. *IFAC-PapersOnLine* **2019**, *52*, 349–354. [CrossRef]
59. Wang, Z.; Zhang, F.; Liu, S.; Xu, D. Consistency between the subjective and objective flood risk and willingness to purchase natural disaster insurance among farmers: Evidence from rural areas in Southwest China. *Environ. Impact Assess. Rev.* **2023**, *102*, 107201. [CrossRef]
60. Ju, X.; Gu, B.; Wu, Y.; Galloway, J.N. Reducing China's fertilizer use by increasing farm size. *Glob. Environ. Chang.* **2016**, *41*, 26–32. [CrossRef]
61. Yu, X.; Schweikert, K.; Li, Y.; Ma, J.; Doluschitz, R. Farm size, farmers? Perceptions and chemical fertilizer overuse in grain production: Evidence from maize farmers in northern China. *J. Environ. Manag.* **2023**, *325*, 116347. [CrossRef]
62. Li, J.; Vatsa, P.; Ma, W. Can mechanized pesticide application help reduce pesticide use and increase crop yield? Evidence from rice farmers in Jiangsu province, China. *Int. J. Agric. Sustain.* **2023**, *21*, 2227809. [CrossRef]
63. Li, Y.; Huan, M.; Jiao, X.; Chi, L.; Ma, J. The impact of labor migration on chemical fertilizer use of wheat smallholders in China-mediation analysis of socialized service. *J. Clean. Prod.* **2023**, *394*, 136366. [CrossRef]
64. Chen, Y.; Ma, X.; Ma, X.; Shen, M.; Chen, J. Does green transformation trigger green premiums? Evidence from Chinese listed manufacturing firms. *J. Clean. Prod.* **2023**, *407*, 136858. [CrossRef]
65. Ren, J.; Gao, T.; Shi, X.; Chen, X.; Mu, K. The impact and heterogeneity analysis of digital financial inclusion on non-farm employment of rural labor. *Chin. J. Popul. Resour. Environ.* **2023**, *21*, 103–110. [CrossRef]
66. Wang, Y.; Yang, A.; Li, Y.; Yang, Q. Effect of e-commerce popularization on farmland abandonment in rural China: Evidence from a large-scale household survey. *Land Use Policy* **2023**, *135*, 106958. [CrossRef]
67. Yu, L.; Nilsson, J.; Li, Y.; Guo, M. Cooperative membership and farmers' environment-friendly practices: Evidence from Fujian, China. *Heliyon* **2023**, *9*, e20819. [CrossRef] [PubMed]
68. Ji, C.; Jin, S.; Wang, H.; Ye, C. Estimating effects of cooperative membership on farmers' safe production behaviors: Evidence from pig sector in China. *Food Policy* **2019**, *83*, 231–245. [CrossRef]
69. Chen, C.; Gan, C.; Li, J.; Lu, Y.; Rahut, D. Linking farmers to markets: Does cooperative membership facilitate e-commerce adoption and income growth in rural China? *Econ. Anal. Policy* **2023**, *80*, 1155–1170. [CrossRef]
70. Jiang, X.; Zhang, X.; Xia, Y. Peer effect on low-carbon practices of firms along the value chain: Evidence from China. *Energ. Econ.* **2023**, *127*, 107102. [CrossRef]
71. Yang, X. Exchanging social support in social commerce: The role of peer relations. *Comput. Hum. Behav.* **2021**, *124*, 106911. [CrossRef]
72. Wang, J.; Tigelaar, D.E.H.; Admiraal, W. Rural teachers' sharing of digital educational resources: From motivation to behavior. *Comput. Educ.* **2021**, *161*, 104055. [CrossRef]
73. Taylor, J.E.; De Brauw, A. Migration and Incomes in Source Communities: A New Economics of Migration Perspective from China. *Econ. Dev. Cult.* **2003**, *52*, 75–101. [CrossRef]
74. Lokshin, M.; Sajaia, Z. Maximum likelihood estimation of endogenous switching regression models. *Stata. J.* **2004**, *4*, 282–289. [CrossRef]
75. Lokshin, M.; Sajaia, Z. Impact of interventions on discrete outcomes: Maximum likelihood estimation of the binary choice models with binary endogenous regressors. *Stata J.* **2011**, *11*, 368–385. [CrossRef]
76. Bascle, G. Controlling for endogeneity with instrumental variables in strategic management research. *Strat. Organ.* **2008**, *6*, 285–327. [CrossRef]