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Digital Environment, Digital Literacy, and Farmers' Entrepreneurial Behavior: A Discussion on Bridging the Digital Divide

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Abstract: To promote sustainable rural development and digital transformation and based on 2018 county-level digital rural indices and microdata from the China Family Panel Studies (CFPSs), this study examines how the digital environment impacts the entrepreneurial behavior of rural households. The results of the study were as follows: (1) The optimization of the digital environment significantly increases entrepreneurial possibilities for farmers, indicating that, the higher the digital rural development index, the easier it is for farmers to start their own businesses. (2) As digital village construction progresses, the impacts of digital hard environments on rural household entrepreneurship decrease, while the influence of digital soft environments increases. (3) Mechanism analysis reveals that digital literacy facilitates farmers' entrepreneurial behavior through the digital environment. Farmers with stronger intentions to participate in commercial activities and information acquisition more actively utilize the digital environment to seek business opportunities and make entrepreneurial decisions. (4) Further analysis reveals an inverted U-shaped relationship between the "second-level digital divide", represented by digital literacy, and the development of digital villages. (5) To fully implement China's Digital Rural Strategy, it is crucial to not only establish digital infrastructure but to also enhance farmers' digital literacy and promote the development of a digital soft environment.

Keywords: digital environment; digital literacy; rural household entrepreneurship; digital divide

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1. Introduction

Digital technologies are key for achieving the United Nations Sustainable Development Goals (SDGs), particularly in rural areas [1]. Digital technologies such as 5G, big data, and artificial intelligence have been integrated into people's daily lives, altering traditional ways of working and studying, and they have also become an essential part of people's social lives [2]. In the past few years, strongly supported by the central government, China's digital economy has rapidly developed. In 2023, the added value of China's core digital economy industries exceeded CNY 12 trillion, accounting for around 10% of China's GDP. With the integration of digital elements, rural elements have been activated, generating new rural industries. This approach optimizes the allocation of resources in rural areas, increasing rural development [3,4]. According to statistics, in 2023, China had 326 million rural netizens, achieving an internet penetration rate of 66.5% in rural areas, a 4.6 percentage point increase year-on-year. However, even though digital infrastructure in rural areas has improved, rural households' uptake of digital technologies lags behind that of urban households. In 2022, compared with the early stage of the "Thirteenth Five-Year Plan", the gap between China's urban and rural internet penetration rates had narrowed by almost

15 percentage points. However, the 2021 survey report of the Chinese Academy of Social Sciences showed that the average literacy score of rural residents in China was a mere 35.1 points, well below the 56.3 points achieved by urban residents [5,6]. We can conclude that the current digital divide is shifting from a "first-level digital divide" to a "second-level digital divide", transforming from inequality of infrastructures to an in digital technology application gap [7]. This shift presents a major shift in terms of the digital divide between urban and rural areas.

Meanwhile, entrepreneurial activities among rural households, which promote the development of new industries and business models in modern agriculture and rural areas, are key for rural revitalization [8]. Traditional agricultural production is generally restricted to singular planting or breeding activities, but rural entrepreneurship can introduce new ideas and technologies to promote agriculture modernization and diversification. Specifically, with rapid urbanization, many farmers lost their land, further increasing the necessity to conduct research on farmers' transformation and development [9]. However, in rural areas, potential entrepreneurs face challenges such as high costs, a lack of entrepreneurial skills, limited access to entrepreneurial opportunities, and difficulty integrating resources [10,11]. These difficulties not only increase barriers to entry for entrepreneurs but also decrease their passion for starting a business. Confronted with these problems, digital technologies provide new possibilities for rural entrepreneurship, with more farmers integrating digital technologies into their entrepreneurial activities, including by running online stores, live-streaming direct sales, and promoting smart agriculture. Digital technologies allow farmers to access market information, technological knowledge, and policy support, allowing their products to penetrate a larger market and achieve maximum value [12]. Thus, we pose the following questions: Does digital construction in rural areas promote rural entrepreneurship? What role does digital literacy play in this process? How can we bridge the digital divide? All of these issues deserve further discussion both theoretically and empirically.

Thus, this study, through data integration, complements the 2018 County-level Digital Rural Index with data from the China Family Panel Studies, providing an in-depth analysis of the positive effects of digital village construction on farmers' entrepreneurial choices, with a focus on digital literacy's pivotal role in this process. Firstly, the study conducts a more detailed analysis of farmers' entrepreneurial decisions from both county-level (meso-level) and household-level (micro-level) perspectives. Secondly, by introducing digital literacy as a key mechanistic variable, the study considers its impact on the relationship between digital villages and farmers' entrepreneurial decisions, revealing how digital literacy acts as a bridge between digital villages and farmers' entrepreneurial choices. This study offers a new perspective on how to enhance farmers' participation in digital village development, thereby influencing the choice of entrepreneurial industries. Lastly, the paper addresses an important question: Can improving the digital environment automatically bridge the digital divide? This analysis provides a more comprehensive understanding of the relationship between the digital environment, digital literacy, and farmers' entrepreneurship.

2. Literature Review

Extensive research has previously been conducted on digital rural development, providing a solid theoretical foundation for this study. The first area of research focuses on how the digital environment influences rural entrepreneurship. Philip et al. (2017) found that digital infrastructure is crucial for digital inclusion in rural communities, directly affecting rural entrepreneurs' access to market opportunities [13]. Salemink et al. (2017) highlighted that digital connectivity gaps in rural areas not only limit entrepreneurial opportunities but also exacerbate urban–rural development inequality [14]. Nambisan (2017) proposed a theoretical framework for digital technology entrepreneurship, emphasizing how digital technology creates new rural entrepreneurship opportunities by reshaping entrepreneurial processes, reducing transaction costs, and breaking geographical limitations [15]. Lin et al.

(2019) empirically demonstrated, using Chinese Taobao villages, that e-commerce platforms significantly enhance rural entrepreneurs' market access and income levels [16].

The second area of research examines the impact of digital literacy on rural development. Ragnedda et al. (2020) introduced the concept of "digital capital", defining digital literacy as a new form of capital, and their research showed that digital literacy significantly affects individuals' participation in and benefits from the digital economy [17]. Park (2017), based on empirical research conducted in rural Australia, found that improving digital skills can enhance rural residents' economic opportunities, although this improvement is significantly influenced by geographical location and social networks [18]. Mariën and Prodnik (2014) adopted a more critical perspective, highlighting that digital literacy gaps may exacerbate existing socioeconomic inequalities, particularly evident in intergenerational transmission [19].

The third area of research examines the formation mechanisms and evolutionary trends influencing the digital divide. Van Dijk (2020) stated that the digital divide has evolved from initial access disparities (first-level digital divide) to skills gaps (second-level digital divide) and benefit disparities (third-level digital divide) [20]. Scheerder et al. (2017) discovered that digital divide research is shifting from assessing technology access to examining digital skills and usage effectiveness [21]. Ragnedda and Ruiu (2020) further developed the digital capital theory, revealing the cumulative interactive relationship between the digital divide and social and human capital [22].

However, a review of the literature shows that the existing research does not focus on the dual dimensions of the digital environment and digital literacy and their impacts on rural entrepreneurship. First, most studies examine rural entrepreneurship through either a digital environment or digital literacy perspective, overlooking potential interactions between the two areas. The digital empowerment of entrepreneurship is a complex process that requires examining the technological environment and human capabilities as an integrated whole. Second, existing research primarily discusses the application of digital technology in rural areas and its economic impact from a macro- or meso-perspective, lacking a microscopic mechanism analysis of household entrepreneurship decisions at both the county and family levels. In particular, when examining digital literacy as a key mechanism variable, few studies have focused on its role in bridging the gap between digital rural development and farmers' entrepreneurship decisions. Third, while scholars have extensively studied the digital divide, there is limited research on the relationship between digital divide indices and digital rural construction. Specifically, key issues remain unresolved, such as whether the digital divide naturally narrows with the growth of digital rural construction and whether there is a non-linear relationship between these two factors. Finally, practical path exploration for effectively bridging rural digital divides and promoting the coordinated development of the digital environment and literacy needs further development.

Thus, this study makes several unique contributions to the existing research: Firstly, from a research perspective, it adopts an innovative dual-level analytical framework that combines county-level digital environment indices with household-level survey data. This approach enables us to capture both the environmental effects of digital village construction and the behavioral responses of individual farmers, providing a more comprehensive understanding of digitization's impacts on rural entrepreneurship. Secondly, this study positions digital literacy as a moderating mechanism, dividing it into three dimensions: digital participation, digital skills, and digital intention. This framework not only allows us to examine not only the importance of digital literacy but also how different aspects of digital literacy interact with the digital environment to influence entrepreneurial decisions. Lastly, this study analyzes the non-linear relationship between the digital divide index and digital village construction, identifying an inverted U-shaped relationship.

3. Theoretical Analysis and Research Hypotheses

3.1. Definition and Framework of the Digital Environment and Digital Literacy

The digital environment is a complex ecosystem created and supported by digital technologies. It consists of the internet, mobile devices, social media platforms, and Internet of Things (IoT) devices. It serves as a visual platform that allows people to participate in digital interactions, information exchange, and social activities, and it has had a profound impact on society, the economy, and culture in the real world [23,24]. Specifically, for villages, this study argues that the digital village represents digital technologies' wide application to and deep integration in rural areas, and it is both a social and technological ecosystem that objectively exists. Therefore, this study employs the "County Digital Rural Index (2018)" published by the Institute of New Rural Development at Peking University to model the development of a village's digital environment, encompassing four aspects: digital infrastructure, the digital economy, digital governance, and digital living in rural areas. Digital infrastructure refers to the digital transformation and enhancement of rural infrastructure, such as communication, internet, and transportation networks. The digital economy refers to the transformation and upgrading of rural industries through the application of digital technologies. Digital governance refers to the application of digital technologies to improve the efficiency and extent of governance. Digital living refers to the daily convenience and comfort brought by digital technologies. To conclude, the digital rural environment is a complicated and vast system, which impacts life, rural infrastructure, the economy, and governance. It, thus, drives rural development.

The concept of digital literacy was first proposed by the Israeli scholar Yoram Eshet-Alkalai [25]. It is considered a crucial skill for modern farmers' entrepreneurship. It can be translated as a farmer's ability to acquire, analyze, process, and apply multiple digital resources and information in agricultural production, operation, and market expansion through modern technologies [26]. There are many measures of digital literacy, the most authoritative of which is the Global Framework for Digital Literacy, developed and released by UNESCO in 2018. This report covers seven key fields and 26 detailed literacy indicators. It draws on existing studies [5,26,27] and measures digital literacy from three perspectives: digital participation, digital skills, and digital intent. Digital participation refers to farmers' use of digital tools and devices, such as smartphones and computers, in agricultural production and operation. Digital skills encompass how effectively farmers employ these digital tools and devices. Digital intent reflects their primary reason for using digital technologies, which is participating in business activities, working, studying, and entertainment.

3.2. Theoretical Analysis of the Impact of the Digital Environment and Digital Literacy on Farmers' Entrepreneurship

Based on the classic Gartner entrepreneurship model [28], entrepreneurial activities revolve around four elements: the entrepreneur, the environment, the organization, and the process. By developing digital villages, rural areas not only empower their "hard environment", but they also transform their "soft environment", which includes their economy, society, and culture. Based on transaction cost theory and a resource-based view, digital infrastructure reduces information asymmetry and transaction costs, making entrepreneurship more feasible for farmers. Simultaneously, the improved access to digital resources enhances farmers' ability to identify opportunities and integrate resources. To be specific, digital infrastructure in rural areas provides farmers with access to information, market connections, and resource integration, reducing information searching, communication, and transaction costs, and increasing the feasibility of entrepreneurship [12]. Through digital infrastructure, rural communities can overcome educational and social barriers from living in the countryside using distance education and online learning platforms; agricultural technologies, for example, have helped farmers to gain entrepreneurial skills [29]. Agricultural technologies will offer farmers new business opportunities as rural economies digitize. Using new models, such as agricultural e-commerce and live

streaming, agricultural producers have created new revenue opportunities. In the digitalized agriculture, rural entrepreneurs can explore emerging industries, upgrade traditional industries, and reimagine value chains [30]. As a result of digitalization, farmers now have greater entrepreneurship opportunities and better conditions for entrepreneurship, encouraging their entrepreneurial intentions. Digitalization also improves village governance by spreading knowledge. Information disclosure, public processes, administrative efficiency, entrepreneurship support, and market regulatory environments are enhanced as a result of digital government services [31]. Besides improving the institutional environment, improving government efficiency, and fostering trust between farmers and governments, digital governance provides farmers with more reliable external support and safeguards when making entrepreneurial decisions. As rural areas become more digitally connected, more high-quality public services can be provided to rural communities through digital platforms [6]. Therefore, farmers' consumption habits change, their social networks expand, and they gain access to entrepreneurship resources and support. In addition, digitalization is increasing farmers' expectations regarding living standards, motivating them to become entrepreneurs. According to the above data, the following hypothesis can be formulated:

H1. *Digital environments positively impact farmers' entrepreneurial decisions.*

However, a farmer's level of digital literacy severely impacts their ability to use these technological resources to increase their productivity and market competitiveness, even though digital villages offer unprecedented entrepreneurial opportunities. To increase their incomes, farmers must have access to information. Digital environments will allow farmers to take advantage of the digital dividend and make more informed and efficient business decisions [29], promoting sustainable rural development.

First, digital participation, which means having access to digital devices, is the foundation of digital literacy. Using digital devices like smartphones and computers can improve farmers' information-gathering abilities, creating a more comprehensive and relevant information base for making entrepreneurial decisions [32]. Furthermore, digital participation has spatial spillover effects on farmers by accelerating information exchange efficiency, reducing entrepreneurial and learning costs through digital technology diffusion, and expanding social interaction boundaries by strengthening social network effects, helping farmers to accumulate social capital and promoting information exchanges with other farmers within the network, thus generating spillover and demonstration effects for neighboring farmers, exposing them to more entrepreneurial opportunities and resources [33,34]. Furthermore, digital tools increase agricultural productivity, supporting entrepreneurial activities more efficiently. In light of this, this study proposes the following hypothesis:

H2. *Digital participation enhances the positive impact of the digital environment on farmers' entrepreneurial decisions.*

Second, digital skills are important. For farmers to be digitally literate, they must also understand how to effectively use digital tools. To improve the quality of their decisions, farmers can identify and filter valuable online information. Farmers can enhance the quality and accuracy of their entrepreneurial decisions by using digital tools to analyze markets, assess risks, and allocate resources. By alleviating financial constraints, farmers can also boost their entrepreneurial decision-making through digital skills. The more digital skills farmers have, the easier it is for them to access financial resources required for entrepreneurship. Online lending, mobile payments, and internet finance allow farmers to more easily access rural financial services [35]. As a result of developing more digital skills, farmers can also discover new market opportunities and business models, stimulating entrepreneurship. As well as enhancing entrepreneurship in rural areas, increasing innovation capacity contributes to an area's economic transformation and development [32]. The following hypothesis was proposed in light of this finding:

H3. *Digital skills enhance the positive impact of the digital environment on farmers' entrepreneurial decisions.*

Thirdly, digital intention, or what farmers use digital technology for, is important. Individuals with clear intentions are more likely to focus on self-improvement and using information effectively when they are digitally literate [36]. Farmers can make better business decisions by using intentional, purposeful learning to gain better industry knowledge and practical skills. For example, digital learning involves acquiring specialized knowledge and high-quality information. To enhance farmers' expertise and build their professional skills, digital platforms provide access to industry-relevant knowledge and market data, along with instructional videos and experience sharing [37]. A farmer's digital intention drives them to purposefully use digital materials in business and learning activities, significantly improving decision-making and increasing entrepreneurial success. Motivation helps them to acquire information, improving their abilities and enabling them to make more accurate risk and opportunity assessments. As a result, this study proposes the following hypothesis:

H4. *Digital intention enhances the positive impact of the digital environment on farmers' entrepreneurial decisions.*

4. Materials and Methods

4.1. Sample Data

The data used in this paper came from two sources. The first is the County-level Digital Rural Index, published jointly by Peking University's Institute for New Rural Development and the Ali Research Institute. The Digital Village Development Index includes both an overall index and several primary and secondary indicators. China Family Panel Studies (CFPSs) is another source of information derived from the Peking University Institute of Social Science Survey. A multistage probability sampling method was used in the 2010 CFPS to cover 25 provinces and 162 counties. Every two years, a survey is conducted to gather data on individuals, households, and villages (communities). Because the County-level Digital Rural Index only includes data from 2018 to 2020, as well as the fact that the COVID-19 pandemic had negative exogenous impacts on farmers' entrepreneurial activities, this study analyzed CFPS data from 2018. Since entrepreneurial decisions are often made collectively at the household level and household heads typically play a significant role in production and daily life decision-making, this study used data at both the household and individual levels, matched them with Digital Rural Index at the county level, and excluded non-rural samples and samples with missing values, ultimately obtaining 3879 observation samples.

4.2. Variable Selection

Dependent Variable: This study allocated rural household entrepreneurial behavior as a dependent variable. Rural household entrepreneurship refers to the complete process through which farmers, relying on their families, identify and leverage entrepreneurial opportunities, integrate entrepreneurial resources, and ultimately establish new organizations, as well as develop new products or provide new services [6]. As part of the CFPS family economic survey, respondents were asked "Have any of your family members engaged in self-employment or private business activity in the past 12 months?" Based on the existing research [9,38], rural household entrepreneurs were defined as households that had engaged in entrepreneurship, with a dependent variable coded as 1. Family members who answered "no" had not engaged in entrepreneurship; the dependent variable was coded as 0.

Independent Variable: The independent variable used in this study was the digital environment. Digital technologies have been integrated into all aspects of human economic, political, cultural, social, and ecological development with new concepts, new industries,

and new models, profoundly influencing human production and life. The digital environment refers to the external conditions necessary for the application and dissemination of digital technologies, including both hard infrastructure (such as digital infrastructure) and soft infrastructure (such as digital culture, digital governance, and digital services). For this study, we used the County-level Digital Rural Index as a proxy for the digital environment, with the digital infrastructure index representing the hard digital environment and the remaining primary indicators (the digitalization index for rural economy; the digitalization index for rural governance; and the digitalization index for rural life) representing the soft digital environment.

Mechanism Variable: This study used digital literacy as a mechanism variable. Digital literacy significantly impacts personal development. The digital environment promotes career development, lifelong learning, and social participation. We divided digital literacy into three dimensions: participation, skills, and intentions. According to the research of scholars such as David Bawden and S.L. KongRong [39–41], we used "leisure internet time" from the CFPS survey to depict digital participation, "whether sending and receiving emails" to represent digital skills, and "the importance of learning, working, socializing, and commercial activities while online" and "the importance of the internet as an information channel" to characterize digital intentions.

Control Variables: Based on existing research [33,42,43], this study employed a combination of household and individual control variables. The household control variables included family size, home ownership, cash and deposits, and household financing. Ownership of a home was a binary variable: households that owned their home or co-owned it with their work unit were coded as 1, whereas households that rented, received free housing from the government or their work unit, or lived with family and friends (i.e., did not own property) were coded as 0. A household's financing consisted of borrowing from banks and borrowing from family and friends. There were six individual control variables: age, age squared, gender, years of education, marital status, and health status. Marital status was a binary variable, with "married (with spouse)" set to 1 and "unmarried, cohabiting, divorced, widowed, etc." set to 0. A CFPS question asked, "How do you perceive your health status?" with the options "Very unhealthy", "Unhealthy", "Average", "Healthy", and "Very healthy" coded as 1, 2, 3, 4, and 5. As shown in Table 1, descriptive statistics are provided for the main variables.

Table 1. Descriptive statistics for variables.

Variables	Definition and Assignment	Mean.	S.D.	Min.	Max.
Digital Rural Index	Total Index for County Digital Rural Development	52.0276	9.898	22.58	82.96
Farmer Entrepreneurship	Yes = 1, No = 0	0.0683	0.252	0.00	1.00
Age	Respondent's age (years)	52.2709	13.735	16.00	91.00
Age Squared	Square of the respondent's age (years)	2920.8592	1427.784	256.00	8281.00
Years of Education	Years of education of respondents (years)	6.1031	4.228	0.00	19.00
Marital Status	Whether the respondent has a spouse: Yes = 1, No = 0	0.8453	0.362	0.00	1.00
Gender	Whether the respondent is male: Yes = 1, No = 0	0.5705	0.495	0.00	1.00
Health Status	Self-assessed health status of respondents	3.1882	1.296	1.00	5.00
Home Ownership	Household property ownership: Yes = 1, No = 0	0.9067	0.291	0.00	1.00
Household Size	Household population size (people)	3.9482	2.006	1.00	21.00
Cash and Deposits	Household cash and deposits (CNY)	2.29×10^{-4}	63,982.502	0.00	160×10^{-4}
Household Financing	Total household financing (CNY)	1.40×10^{-4}	44,138.944	0.00	1.00×10^{-4}

4.3. Model Design

As farmer entrepreneurship was a binary variable, this paper employed a Probit model (Equation (1)) to examine the impact of the digital environment on farmer entrepreneurship. The specific model was defined as follows:

$$\text{Entpr}_{ij} = \alpha + \beta \text{DigV}_j + \sum \gamma Controls_{ij} + \lambda_k + \varepsilon_{ij} \quad (1)$$

where Entpr_{ij} is the dependent variable, representing a dummy variable indicating whether the ith household in the jth county is an entrepreneur; it takes a value of 1 if the household is engaged in entrepreneurship, and 0 otherwise.DigV_j is the independent variable, indicating the digital rural construction index for the jth county, with β being its corresponding impact coefficient. If $\beta > 0$, it suggests that the digital environment positively promotes farmer entrepreneurship. The variable Controls_{ij} includes control variables such as household size and home ownership, as well as household head characteristics like age and gender. λ_k represents regional fixed effects. To account for regional differences, we also controlled for provincial-level fixed effects. ε_{ij} is the random disturbance term. The model uses county-level clustered robust standard errors.

Furthermore, this study employed group regression and moderation effect models to examine the moderating role of digital literacy (Equation (2)). The group regression model was the same as the baseline model but restricted the sample based on the moderating variable; the moderation effect model was set as follows:

$$\text{Entpr}_{ij} = \alpha + \beta \text{Moderate}_{ij} \times \text{DigV}_j + \sum \gamma \text{Controls}_{ij} + \lambda_k + \varepsilon_{ij} \quad (2)$$

where Moderate_{ij} is the variable to be tested. In this study, based on existing research [5,9,44], we used "leisure internet usage time" to represent digital participation, "whether emails are sent and received" to represent digital skills, and "the importance of learning/work/socializing/entertainment/commercial activities while online" and "the importance of the internet as an information channel" to represent digital intentions.

5. Results

5.1. Benchmark Regression

A parameter estimation based on Model (1) is conducted to examine the impact of the digital environment on farmers' entrepreneurship by gradually adding provincial fixed effects and household and individual control variables while incorporating the core explanatory variables into the model. A benchmark regression is presented in Table 2. Column (1) provides a simple estimation of the baseline model without controlling for relevant factors, which may result in bias due to omitted variables. In Columns (2), (3), and (4), provincial fixed effects and individual- and household-level control variables are gradually introduced to address potential omitted variable-related biases. The empirical results are robust after adding control variables and fixed effects in a step-by-step manner. Under various combinations of control variables, the regression coefficients for farmers' entrepreneurship are consistently positive, and they pass the significance test when they reach at least the 5% level, suggesting that the digital environment effectively promotes farmers' entrepreneurship. Thus, Hypothesis 1 is validated.

A regression analysis of the impact of the digital hard and soft environments on farmer entrepreneurship is presented in Table 3. Despite positive regression coefficients for farmer entrepreneurship, the digital hard environment, represented by the digital infrastructure index, does not significantly influence farmer entrepreneurship. A significant degree of farmer entrepreneurship is promoted by the digital soft environment, such as the digitalization of rural economies, rural governance, and rural lifestyles. Therefore, the digital hard environment often develops before the digital soft environment. This trend has gradually lessened as digital rural areas have been constructed, meaning that the digital hard environment has less of an impact on farmer entrepreneurship.

Table 2. Baseline regression results.

Variables	(1)	(2)	(3)	(4)
	Farmers' Entrepreneurship			
Digital Rural Index	0.0136 ***	0.0159 ***	0.0136 **	0.0152 ***
	(3.3559)	(2.8881)	(2.3397)	(2.5921)
Age			0.0380 **	0.0434 **
			(2.1194)	(2.3042)
Age Squared			−0.0005 ***	−0.0005 ***
			(−2.6366)	(−2.6339)
Years of Education			0.0470 ***	0.0451 ***
			(4.3342)	(4.0590)
Marital Status			0.1510	0.0588
			(1.5261)	(0.5502)
Gender			0.0494	0.0444
			(0.7032)	(0.6151)
Health Status			0.0162	0.0153
			(0.6279)	(0.6079)
Home Ownership				−0.3142 ***
				(−3.3507)
Household Size				0.0624 ***
				(3.6175)
Cash and Deposits				0.0000 ***
				(3.0989)
Household Loans				0.0000 ***
				(4.8981)
Constant	−2.2109 ***	−2.2920 ***	−3.2485 ***	−3.4992 ***
	(−9.9742)	(−6.5347)	(−6.4001)	(−6.6924)
Provincial Fixed Effects	No	Yes	Yes	Yes
Observations	3879	3832	3832	3832

Note: Values in parentheses are robust standard errors clustered at the county level. ** and *** indicate significance at the 5%, and 1% levels, respectively.

Table 3. The impact of the digital soft and hard environment on farmers' entrepreneurship.

Variables	(1)	(2)	(3)	(4)
	Digital Hard Environment	Digital Soft Environment		
Digital Infrastructure Index	0.0016			
	(0.3990)			
Digitalization Index for Rural Economy		0.0136 **		
		(2.1558)		
Digitalization Index for Rural Governance			0.0077 ***	
			(3.5665)	
Digitalization Index for Rural Life				0.0104 **
				(2.4733)
Control Variables	Yes	Yes	Yes	Yes
Provincial Fixed Effects	Yes	Yes	Yes	Yes
Observations	3832	3832	3832	3832

Note: Values in parentheses are robust standard errors clustered at the county level. ** and *** indicate significance at the 5% and 1% levels, respectively.

5.2. Endogenous Treatment

This study uses omitted variables to address potential endogeneity issues. Based on the existing literature [45], the internet penetration rate in farmers' communities in 2012 is an instrumental variable for the digital environment. A two-stage least-squares regression model (2SLS) is used to regress the instrument variable. On one hand, the rural digital environment is highly positively correlated with internet penetration and application, proving the relevance of the instrumental variable; on the other hand, the impact of internet

penetration in the past on farmer entrepreneurship in the future within the study region is decreasing, satisfying the exogenous nature of the instrumental variable. Based on the two-stage least-squares regression, Table 4 presents the regression results. The first-stage analysis shows an F-statistic of 185.76, and the *p*-values for both Wald tests are less than 0.001, indicating that weak instrumental variables are not a concern. A significant positive correlation exists between the instrumental variable and the endogenous variable, i.e., the Digital Rural Index. According to the second-stage regression results, the Digital Rural Index coefficient remains significantly positive at 1% after introducing the instrumental variable. Digital rural areas continue to significantly contribute to farmer entrepreneurship, as evidenced by this study.

Table 4. Regression results for the first and second stages.

(1) First Stage		(2) Second Stage	
	Digital Rural Index		Farmers' Entrepreneurship
Internet Penetration Rate	0.3293 ***	Digital Rural Index	0.0958 ***
	(0.0319)		(0.0333)
Control Variables	Yes	Control Variables	Yes
Provincial Fixed Effects	Yes	Provincial Fixed Effects	Yes
F-Statistic	185.76		
Wald Test *p*-value	0.0005		
Observations	3,407	Observations	3407

Note: Since the weakiv command does not support clustered robust standard errors, the values in parentheses are ordinary standard errors. *** indicate significance at the 1% levels.

5.3. Test for Robustness

To achieve reliable regression results, the following robustness tests were conducted. Firstly, the core explanatory variable was replaced with the Digital Economy Index of the region where the farmers live. According to Column 1 of Table 5, the digital economy continues to significantly and positively impact farmer entrepreneurship. A Logit model was substituted for the baseline Probit model to mitigate the model specification effects. Column 2 of Table 5 shows that the coefficient of the Digital Rural Index is significant and positive at the 1% level. The continuous variables were winsorized at the 5% level to reduce the impacts of outliers on the results. Column 3 of Table 5 shows that the Digital Rural Index coefficient is positive and significant at 1%. Also, when 50% of the sample was randomly selected for regression, the results, as shown in Column 4 of Table 5, indicated that the impact of the Digital Village Index on rural entrepreneurial activities was significantly positive. In summary, the results of this study demonstrate good robustness.

Table 5. Robustness check.

Variables	**(1) Probit Model**	**(2) Logit Model**	**(3) Winsorize**	**(4) Randomly Select 50% of the Sample**
Digital Economy Index	4.3606 **			
	(1.8864)			
Digital Rural Index		0.0321 ***		
		(0.0120)		
Digital Rural Index			0.0201 ***	
			(0.0070)	
Digital Rural Index				0.0250 ***
				(0.0077)
Control Variables	Yes	Yes	Yes	Yes
Provincial Fixed Effects	Yes	Yes	Yes	Yes
Observations	3425	3832	3832	1915

Note: Since the weakiv command does not support clustered robust standard errors, the values in parentheses are ordinary standard errors. ** and *** indicate significance at the 5% and 1% levels, respectively.

5.4. Mechanism Analysis

5.4.1. Digital Environment, Digital Participation, and Farmers' Entrepreneurship

Digital participation is essential for the promotion of entrepreneurship among farmers in the digital environment. In this study, proxies for digital participation are used, such as whether a farmer owns a computer or mobile internet device. In addition, it utilizes leisure time spent online as another variable. This study examines the role of digital participation in moderating the effect of the digital environment on farmers' entrepreneurship. Considering that whether a computer or mobile internet is available is a binary variable, this study conducts a subgroup regression for both the non-internet-access group and the internet-access group, as shown in Columns 1 and 2 of Table 6. The results indicate that for the internet-access group, the digital environment has a greater impact on farmer entrepreneurship compared to the baseline regression and is significant at the 1% level. In contrast, for the non-internet-access group, the digital environment has a smaller effect on the promotion of farmer entrepreneurship and does not pass the significance test. The non-internet-access group still accounts for 64% of the whole sample. Moreover, the results of using leisure time spent online as a moderating variable in Equation (2) are presented in Column 3 of Table 6. Farmers' entrepreneurship is positively influenced by spending time in the digital environment. Accordingly, digital participation increases the positive influence of the digital environment on farmers' entrepreneurial decisions, which supports Hypothesis 2.

Table 6. Digital environment, digital participation, and farmers' entrepreneurship.

Variables	(1) Not Connected	(2) Connected	(3)
Digital Rural Index	0.0033		0.0125 **
	(0.0082)		(0.0060)
Digital Rural Index		0.0261 ***	
		(0.0071)	
Digital Rural Index × Leisure Internet Time			0.0003 ***
			(0.0001)
Control Variables	Yes	Yes	Yes
Provincial Fixed Effects	Yes	Yes	Yes
Observations	2403	1335	3824

Note: Values in parentheses are robust standard errors clustered at the county level. ** and *** indicate significance at the 5% and 1% levels, respectively.

5.4.2. Digital Environment, Digital Skills, and Farmers' Entrepreneurship

Digital skills are essential methods for ensuring farmers' participation in entrepreneurial activities in the digital environment. This study uses email (whether a farmer sends or receives emails) as a proxy variable for digital skills. Given that farmers acquire digital skills through both self-learning and learning from others, this paper examines digital skills' impact on rural household entrepreneurship in the digital environment from the perspectives of individual skills and social support. Specifically, individual skills are measured based on whether a farmer sends or receives emails, and social support is measured by the proportion of individuals in the same village who have access to email. First, individual skills and social support were separately introduced as moderating variables in Equation (2), with the results illustrated in Columns 1 and 2 of Table 7. We concluded that individual skills and social support increase the digital environment's impact on rural entrepreneurship at the 10% and 1% significance levels, respectively. In the following step, social support was divided into two groups, weak and strong, based on the median value, and separate regressions were performed for each group. Farmers who had poor social support were not hugely impacted by the digital environment in terms of their entrepreneurship. The digital environment had a stronger impact on farmers with strong social support than those with weak social support, achieving significance at a 1% significance level. Digital skills enhance farmers' entrepreneurial decision-making in the digital environment, confirming Hypothesis 3.

Table 7. Digital environment, digital skills, and farmers' entrepreneurship.

Variables	(1)	(2)	(3) Weak Social Support	(4) Strong Social Support
		Farmers' Entrepreneurship		
Digital Rural Index	0.0146 ***	0.0074	−0.0052	0.0317 ***
	(0.0058)	(0.0065)	(0.0102)	(0.0096)
Digital Rural Index × Self Skills	0.0052 *			
	(0.0030)			
Digital Rural Index × Social Support		0.0470 ***		
		(0.0135)		
Control Variables	Yes	Yes	Yes	Yes
Provincial Fixed Effects	Yes	Yes	Yes	Yes
Observations	3832	3696	1773	1964

Note: Values in parentheses are robust standard errors clustered at the county level. * and *** indicate significance at the 10% and 1% levels, respectively.

5.4.3. Digital Environment, Digital Intentions, and Rural Entrepreneurship

As the digital economy evolves, farmers have the option of adapting or falling victim to the "digital pacifier" effect. Digital intentions are crucial in this context. This study examines the moderating effects of digital intentions, such as learning, working, socializing, entertaining, engaging in business activities, and information acquisition, on the digital environment's role in promoting entrepreneurship among rural households. Specifically, this study measures the digital intentions of rural households by assessing the importance that they place on learning/working/socializing/entertaining/conducting business activities online and the significance of the internet as an information channel. These intentions are then incorporated as moderating variables into Equation (2), with the results presented in Table 8. The table shows that the digital environment has a significant positive impact on rural entrepreneurship as a result of learning, work, socializing, entertainment, business activities, and the acquisition of information. In order of effect size, business activities, information acquisition, work, learning, socializing, and entertainment are the most influential factors. Overall, clear digital intentions, such as information searching and knowledge acquisition, enhance the influence of the digital environment on rural entrepreneurship decisions. Thus, Hypothesis 4 is confirmed.

Table 8. Digital environment, digital intent, and farmers' entrepreneurship.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
Digital Rural Index	0.0135 **	0.0134 **	0.0118 *	0.0131 **	0.0111 *	0.0089
	(2.3012)	(2.2827)	(1.9466)	(2.2199)	(1.8714)	
Digital Rural Index × Importance of Learning	0.0013 ***					
	(3.6684)					
Digital Rural Index × Importance of Work		0.0015 ***				
		(3.7376)				
Digital Rural Index × Importance of Socializing			0.0012 ***			
			(3.1984)			
Digital Rural Index × Importance of Entertainment				0.0009 ***		
				(2.5946)		
Digital Rural Index × Importance of Business Activities					0.0028 ***	
					(7.6632)	
Digital Rural Index × Importance of Information Acquisition						0.0018 ***
						(5.0597)
Control Variables	Yes	Yes	Yes	Yes	Yes	Yes
Provincial Fixed Effects	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3832	3832	3831	3831	3832	3831

Note: Values in parentheses are robust standard errors clustered at the county level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

6. Further Discussion: Bridging the Digital Divide

6.1. Measuring the Digital Divide

Our previous analysis demonstrates that the digital environment influences farmers' entrepreneurship through digital literacy's moderating effect. This finding raises a deeper question: As the digital environment continuously improves, will the digital literacy gap among farmers naturally narrow? In other words, what is the relationship between digital rural construction and the digital divide? Understanding this relationship is crucial for evaluating the long-term effectiveness of digital rural construction. Digital literacy represents the "secondary digital divide", which is the subject of further discussion. There is a digital divide between different groups in accessing and utilizing emerging information technologies to improve their living conditions, maintaining existing economic inequality and wealth gaps in the digital age [46,47]. In addition to the digital divide between regions and urban–rural areas, this divide exists within rural areas, exacerbating inequalities in income and opportunities among rural residents [48].

As existing research does not fully capture the digital divide, this study measures the digital divide index in the rural areas of sample counties using data from previous studies [5,45]. Since the digital divide is a disparity in digital literacy among different entities, this study first measures the digital literacy of farmers. Referring to existing research, factor analysis is employed to reduce the dimensionality of the eight variables across three dimensions of farmers' digital participation, digital skills, and digital intentions; the variables included are internet access, leisure internet usage time, personal skills, social support, and the importance of internet use for learning, work, socializing, and business activities, as well as the importance of the internet as an information channel. Given that entertainment has the least moderating effect on promoting farmer entrepreneurship in the digital environment, it is not included. The KMO value is 0.903, greater than 0.8, and Bartlett's test of sphericity chi-square value is 48,547.213, which passes the 1% significance-level test, indicating that factor analysis is appropriate. Ultimately, one common factor, namely digital literacy, is extracted. Furthermore, the Gini coefficient of farmers' digital literacy in each county is calculated; this measure represents the digital divide index in the rural areas of that county. To ensure the reliability of the calculation results, this study excludes counties with fewer than 30 samples.

6.2. Bridging the Digital Divide

Due to the objective law of technology diffusion, with new technology uptake spreading from the center to the periphery, the emergence of a digital divide in the construction of digital villages is inherently inevitable, as are practical differences in economics, knowledge, abilities, and willingness to accept new things among rural households [49]. However, as digital infrastructure continues to improve, digital devices and technologies become more prevalent, and digital application scenarios diversify, so disadvantaged groups can increasingly access and utilize digital technologies, suppressing and bridging the digital divide [50]. Could there be a "digital Kuznets curve", similar to the Kuznets curve, between the construction of digital villages and the digital divide in rural areas? With the construction of digital villages, can the digital divide be bridged? An inverted U-shaped relationship can be observed between the previously measured digital divide index and the Digital Rural Index in Figure 1.

To further confirm the relationship between the two factors, the regression model is set as follows (Equation (3)): i is the county, DD_i is the digital divide index, $DigV_i$ is the Digital Rural Index, and $DigV_i^2$ is the squared term of the Digital Rural Index. $Controls_i$ includes county-level control variables, such as regional GDP, the ratio of the added value of secondary and tertiary industries to regional GDP, year-end outstanding loans from financial institutions, and local fiscal general budget expenditures. ε_i is the

random disturbance term. The model uses provincial-level clustered robust standard errors as follows:

$$DD_i = \alpha + \beta DigV_i + \varphi DigV_i^2 + \sum \gamma Controls_i + \varepsilon_i \quad (3)$$

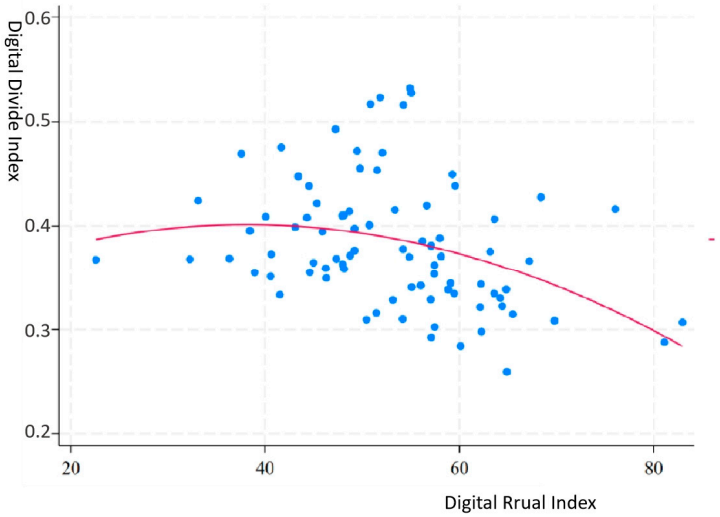

Figure 1. A scatter plot of the Digital Rural Index and the digital divide index with quadratic fitting.

A table displaying the regression results is provided in Table 9. When only the linear impact of digital rural development on the digital divide is considered, regardless of whether control variables are included, the coefficient of the Digital Rural Index is significantly negative at 5%. As a result, counties with a higher Digital Rural Indices have a smaller digital divide between their urban and rural areas. Regardless of whether control variables are included, when the square term of the Digital Rural Index is added, the square term coefficient remains significantly negative when it reaches at least the 5% level, and linear and quadratic terms have opposite signs. Incorporating control variables into Column 4, which provides a reference, confirms the inverted U-shaped relationship between the Digital Rural Index and the digital divide index.

Table 9. Bridging the digital divide.

	Digital Rural Index			
Variables	**(1)**	**(2)**	**(3)**	**(4)**
Digital Divide Index	−0.0018 ***	0.0045	−0.0018 **	0.0073 *
	(−3.8463)	(1.6072)	(−2.6467)	(2.0649)
Square of the Digital Rural Index		−0.0001 **		−0.0001 **
		(−2.2217)		(−2.4454)
Control Variables	No	No	Yes	Yes
Observations	84	84	84	84

Note: Values in parentheses are robust standard errors clustered at the county level. *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

When making further calculations, the digital divide converts into a Digital Rural Index of 40. When the Digital Rural Index is less than 40, the digital divide increases; when the Digital Rural Index reaches 40, the digital divide decreases with the increase in the Digital Rural Index. With the continued growth of digital rural construction, the digital divide in rural areas will likely gradually narrow.

7. Research Conclusions and Implications

7.1. Research Conclusions

Based on the micro-matched data of the 2018 National County-level Digital Rural Index and the China Family Panel Studies (CFPSs), this paper empirically examines the impact of the digital environment on farmers' entrepreneurial decisions and the influence of digital literacy on this process. Furthermore, it considers strategies for bridging the digital divide. The findings of this study are as follows: (1) The development of the digital environment has a significant positive impact on farmers' entrepreneurial decisions, meaning that as the Digital Village Development Index increases, farmers are more likely to make entrepreneurial decisions. (2) With the continuous growth of digital village construction, the digital hard environment's influence on farmers' entrepreneurship is gradually diminishing, while the impact of the digital soft environment is becoming more pronounced. This conclusion remains robust after considering the model's endogeneity. (3) The analysis of digital literacy as a mechanistic variable reveals that digital participation, digital skills, and digital intentions influence the promotion of farmers' entrepreneurship by the digital environment. Notably, apart from their own digital skills, external social support is also an influencing factor. Additionally, from the perspective of digital intentions, farmers with stronger intentions to engage in commercial activities and information acquisition more actively leverage the digital environment to seek business opportunities and make entrepreneurial decisions. (4) When discussing bridging the digital divide, we find that there is an inverted U-shaped relationship between the "secondary digital divide", represented by digital literacy, and the Digital Rural Index, indicating that with the construction of digital villages, especially the improvement of the digital soft environment, the digital literacy divide among farmers can be gradually bridged. This study argues that digital village development can mitigate the adverse effects of the digital divide on farmers' entrepreneurship, and farmers' digital literacy is an important "moderator" that better facilitates the positive impact of digital village development on farmers' entrepreneurship.

7.2. Policy Recommendations

These conclusions lead to the following policy recommendations:

Continue strengthening digital rural construction: The government should increase investment and develop differentiated construction plans tailored to local conditions. While regions with established infrastructure should improve digital services and application levels, areas with weak foundations should prioritize network coverage and infrastructure issues. To ensure stable operation and support for rural digital infrastructure, a long-term maintenance mechanism should be developed. A hard digital environment should be built, but a soft digital environment must also be developed. Using technologies such as big data and cloud computing, digital platforms for rural social governance should be established, enhancing the scientific and refined management of rural governance. To enrich the lives of farmers, digital cultural products tailored to their characteristics should be encouraged.

Improve farmers' digital literacy: A comprehensive digital skills training program must be implemented, tailored to the needs of farmers of various ages and backgrounds. There should be coverage of basic smartphone and computer operations, internet use, and more advanced applications like e-commerce and smart agriculture. Governments should establish digital learning centers at the village level, equipped with computers and internet access in public venues, such as village committees or cultural stations. A professional or volunteer should provide regular guidance and training. Developing a "digital leader" program is essential, selecting and training those with high levels of digital literacy to encourage other farmers to learn and use digital technologies.

Encourage digital innovation and entrepreneurship among farmers: Counties and townships should establish incubation centers to support and guide entrepreneurs. E-commerce platforms and new media should be designed to develop rural e-commerce. Using technologies such as the Internet of Things and big data to develop "Internet+" modern agriculture is essential. For rural specialty industries' digital transformation, rural

specialty industries, such as handicrafts, rural tourism, and others, should use digital technologies to enhance product design, production, and marketing.

Address the deeper issues of the digital divide: Those at a digital disadvantage, including the elderly and low-income populations, require special assistance, such as free or low-cost digital devices for internet access and digital skills training. The ability to share data in rural areas could facilitate the exchange of information between governments, businesses, and social organizations. By analyzing and mining data, farmers can receive more precise and personalized services.

Promote the deep integration of digital transformation and sustainable development: We should encourage the development of green and low-carbon digital technologies and support the exploration of sustainable rural e-commerce entrepreneurial models to achieve coordinated development between economic growth and environmental protection. Digital technology empowerment, facilitating farmers' innovation and entrepreneurship, and establishing a long-term mechanism for sustainable rural development are all key to achieving this goal.

7.3. Future Research Prospects

Although this study revealed the digital environment's positive role in promoting farmer entrepreneurship and its underlying mechanisms, multiple research directions are worthy of further exploration. In particular, in terms of the cost–benefit assessment of digital rural construction, future research could incorporate the cost elements of digital rural construction into the analytical framework, enabling quantitative analysis of the comprehensive benefits of digital rural construction. Furthermore, future research should study the optimal investment strategies for digital rural construction, especially those for achieving optimal resource allocation between digital infrastructure development and digital literacy cultivation, providing more operational guidance for government decision-making.

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