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Promotion of rural industrial revitalization through the development of the rural digital economy

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Introduction: The rise of digital technologies has reshaped rural development strategies, offering new opportunities for industrial revitalization in agricultural regions. In China, the rural digital economy—spanning both infrastructure and digital service adoption—has emerged as a critical driver of localized innovation. This study explores the mechanisms through which digital transformation influences rural industrial upgrading. Using a structured survey in a major navel orange production area, the study examines how hardware and software elements of digitalization affect farmers' innovation intentions, entrepreneurial behaviors, and outcome perceptions. By identifying heterogeneity across business models and farm scales, the study provides empirical insights into the role digital inclusion plays in revitalizing rural economies.

Methods: This study draws on 1,042 survey responses from a representative navel orange-producing region in China. Key variables reflect three dimensions of rural industrial revitalization: innovation intentions, entrepreneurial action, and perceived outcomes. The independent variables reflect the development of the digital economy through two dimensions: digital infrastructure and service usage. Ordered Probit and OLS models were applied to estimate relationships, with robustness checks performed using instrumental variables to address endogeneity. Instrument relevance and validity were confirmed through standard econometric tests. Heterogeneity was further examined by disaggregating impacts across production types and farm sizes.

Results: Findings demonstrate that both infrastructure (hardware) and service use (software) aspects of the rural digital economy significantly enhance farmers' innovation intention, entrepreneurial engagement, and outcome perception. These effects remain statistically significant and become more pronounced after addressing endogeneity. While hardware shows limited effects across different business types, software-related digital adoption significantly benefits most producers. Additionally, the digital economy's impact on entrepreneurial action and outcomes is more pronounced among medium- and large-scale farms than smaller producers. Three mechanisms—employment, income growth, and improved well-being—mediate this effect.

Discussion: The results highlight the transformative potential of rural digital economy development in advancing industrial revitalization. Tailored digital infrastructure, training, and inclusive service access are critical to unlocking innovation capacity at the household level. To enhance equitable digital transformation in agriculture, policies should prioritize narrowing digital divides in underdeveloped regions and facilitate the adoption of adaptable digital farming models, including smart production systems and agricultural

traceability platforms. Beyond infrastructure, broader institutional, household, and community efforts—ranging from financial literacy to organizational participation—must complement digital investment. Future studies should expand the scope, adopt longitudinal designs, and explore institutional drivers to deepen the understanding of sustainable rural transformation.

KEYWORDS

digital economy development, localized innovation and entrepreneurship, rural digital economy, rural industrial revitalization, agricultural economics, digital economics

1 Introduction

As a vital component of the digital economy, rural digital economy development propels the transformation of rural production methods, lifestyles, and governance (Li and Liu, 2021; Zhang et al.,2023). This development is critical in fostering new competitive advantages in rural industries as it drives structural upgrades and enhances the innovation vitality of rural industries (Lu et al., 2025). Empirical evidence indicates that the continuous development and widespread application of new digital technologies significantly accelerates the integration of modern production elements with traditional rural industries, thus aiding the development of new industries, business models, and patterns in rural areas (Gao and Liu, 2020; Yu et al., 2021; Chen, 2025; Liang and Qiao, 2025).

Specifically, accelerating the development of the rural digital economy and steadily advancing the digital transformation of rural industries are essential for enhancing agricultural productivity and promoting supply-side structural reforms. These efforts also contribute to strengthening the agricultural foundation, increasing farmers' income, and ensuring a seamless transition from poverty alleviation to rural revitalization (Zhang et al., 2021; Zhou et al., 2023; Xu and Yang, 2025). Therefore, researching the role of the rural digital economy in revitalizing rural industries has significant practical relevance in the context of rural revitalization.

The growing integration of digital technologies into rural development strategies marks a significant shift in how rural transformation is approached. Within this broader trend, the rural digital economy—characterized by the adoption of tools such as e-commerce, cloud computing, artificial intelligence, and the Internet of Things—has shown considerable potential in shaping agricultural practices, governance processes, and industrial renewal in rural settings (Deng et al., 2023; Chen, 2025). However, current understanding of how these technologies systematically support rural industrial revitalization remains limited, highlighting the need for a more in-depth and evidence-based investigation. Recent research has demonstrated that digital solutions can be crucial in improving agricultural productivity and efficiency. Technologies like precision farming, mobile-based advisory services, and real-time market data platforms allow farmers to make better decisions and optimize resource use (Huang et al., 2021; Li et al., 2021). At the same time, digital marketplaces have enabled producers in remote areas to directly connect with consumers, reducing reliance on intermediaries and increasing profits (Wang and Zhang, 2019; Chen and Wang, 2022; Zhang et al., 2023). This connectivity improves market access and encourages the development of new types of rural industries, such as agritourism and digital entrepreneurship (Jin et al., 2022). Access to infrastructure—especially the broadband internet and mobile networks—has emerged as a key factor shaping how effectively rural communities engage with digital systems. Areas with stronger digital infrastructure show higher rates of entrepreneurship and employment growth (Bi, 2024; Luo et al., 2022). However, disparities between regions remain a challenge. Many rural communities continue to face limited connectivity, restricting their ability to benefit equally from digital transformation (Fong, 2009). Bridging this digital divide is essential for ensuring inclusive rural revitalization. Beyond production and commerce, digital platforms are increasingly used to improve local governance. Digital tools help rural authorities deliver services, manage public resources, and interact with residents more efficiently (Zhang et al., 2023; Yin et al., 2024). These innovations support the broader institutional framework required for sustainable development, including better coordination and transparency in rural planning (Meginnis et al., 2020; Zhang et al., 2025; Kong and Chen, 2024; An et al.,2024). Despite these advances, many studies continue to examine only isolated components of the rural digital economy, such as yield improvements or poverty reduction, without addressing how these outcomes contribute to broader industrial transformation (Yu et al., 2021). Exploration of how digitalization interacts with traditional rural industry clusters or how institutional and behavioral factors influence technology adoption is also limited (Sun et al., 2023; Ren, 2023; Zhang and Zhang, 2023). For example, issues like digital literacy, trust in online platforms, and resistance to change remain under-discussed despite their importance in shaping the impacts of digital interventions (Ahmad et al., 2021). From a policy perspective, these research gaps are highly relevant. As many low- and middle-income countries prioritize rural digital infrastructure as part of revitalization plans, understanding both the benefits and limitations of such investments is crucial. Without targeted, context-sensitive approaches, these efforts may inadvertently reinforce spatial inequalities rather than reduce them (Li and Liu, 2020; Zhao et al., 2021).

A growing body of research highlights the transformative role of the rural digital economy in enhancing farm-level productivity, modernizing governance, and stimulating industrial renewal in rural areas. Much of the current literature utilizes macro-level data to investigate how digital infrastructure, the growth of e-commerce, and regional development indicators contribute to rural revitalization, particularly in the context of developing countries. While these studies offer valuable insights, two key limitations remain. First, micro-level evidence based on household experiences is lacking, which makes it difficult to fully understand the real-world implications of digital tools on agricultural practices and industrial behavior. Second, the underlying mechanisms through which digitalization influences rural revitalization are often treated simplistically, and few studies explore

variations across different types of industries or production scales. To address these gaps, this study conducts an empirical investigation that offers two main contributions:

(1) A Micro-Level Empirical Approach: Rather than relying on secondary data, this study draws on a large-scale field survey comprising 1,042 farm households in a leading navel orange-producing region in China. Using this dataset, we build a composite index of rural digital economy development based on two dimensions: *infrastructure availability* (e.g., internet access and device ownership) and *functional digital literacy* (e.g., platform usage and digital engagement skills). We assess rural industrial revitalization using a three-stage framework that captures *intentions*, *actions*, and *outcomes*. The findings, verified using Ordered Probit and OLS models, reveal a robust and statistically significant relationship between digital development and rural industrial advancement—even after controlling for potential endogeneity.

(2) Mechanism Exploration and Heterogeneity Analysis: The study further identifies three indirect channels through which digital engagement contributes to industrial revitalization: expanding employment opportunities, raising household incomes, and improving subjective well-being. Additionally, the analysis uncovers heterogeneity in outcomes based on industry category and business size, suggesting that digital interventions do not yield uniform results across rural contexts. These findings advance current theory on rural digitalization and offer practical guidance for tailoring policy initiatives to local needs.

The study uses a structured research framework based on primary data collection with a stratified sampling method to ensure diverse representation. Key constructs were measured using validated indicators. To accommodate both ordinal and continuous dependent variables, appropriate econometric models—including ordered probit and OLS—were employed. Robustness checks were conducted to address potential issues of endogeneity and multicollinearity. The research bridges digital access, user capabilities, and socio-economic effects, offering a holistic view of rural transformation processes.

2 Theoretical framework and hypotheses development

Since Don Tapscott first introduced the concept of the digital economy in 1996, scholars have expanded its definition to various extents (Tapscott, 1996). This study argues that the rural digital economy incorporates information and data as vital production materials in developing rural industries, accelerating agricultural technological innovation, reshaping new digitalized rural industries, and achieving high-quality rural economic development (Bukht and Heeks, 2018; Yu et al., 2021; Chen, 2025; Liu et al., 2023). Concurrently, this study interprets rural industrial revitalization as the comprehensive rejuvenation of rural industries based on agricultural resource diversity and climatic advantages guided by government policies supporting agriculture that promote shared prosperity among farmers, improve farmer employment, and enhance their well-being (de Janvry and Sadoulet, 2001; Haggblade et al., 2010; Peng and Dan, 2023). Rural industrial revitalization includes revitalizing specialized agriculture, leisure agriculture, agricultural product processing, handicrafts, rural tourism, and e-commerce (Pan et al., 2024; Chen and Long, 2024; Li and Gan, 2025). This implies reconstructing a rural industrial system characterized by distinct regional features, active innovation and entrepreneurship, various business models, and closely linked interests (Audretsch and Belitski, 2017; Bhatia-Kalluri, 2021). The hypothesis that developing the rural digital economy promotes rural industrial revitalization manifests several aspects.

As a developing agricultural country, farm households in China remain a fundamental force of agricultural development and food production. The effectiveness of their innovative entrepreneurship significantly influences the progress of rural industrial revitalization (Yin et al., 2022). This practice has shown that the revitalization of traditional rural industries is inseparable from the participation of farm households, and that the development of emerging rural industries relies heavily on their support. Innovation and entrepreneurship are vital pathways for farm households to participate in rural industrial revitalization. Compared with the past, under the development of the rural digital economy, conditions for localized innovation and entrepreneurship by farm households have improved. For instance, Barnett et al. (2019) argue that although regional heterogeneity exists in the internet access, social capital, and financing access effects on farmers' innovation and entrepreneurship, these effects are undeniably the basic conditions for enhancing farmers' willingness to localize their innovation and entrepreneurship. Developing the digital economy significantly stimulates passion for mass innovation and entrepreneurship (Tan and Li, 2022; Feng et al., 2023). He et al. (2024) and Che et al. (2024) believe that the widespread application of the rural mobile internet directly influences agricultural production and management activities, triggering new opportunities for farm household innovation and entrepreneurship. This is primarily because the use of rural mobile internet significantly improves farm households' access to market resources, social network transmission, and social capital fundraising channels, all of which are conducive to enhancing their willingness to innovate and start businesses. Song et al. (2024) view the empowerment of the digital economy as a fundamental basis for farm household innovation and entrepreneurship. The digital economy provides new opportunities to revitalize market entities and promote innovation and entrepreneurship within farm households (Zhang et al., 2021). Developing the rural digital economy can significantly expand the channels through which farm households access information, promote investment in human capital, and enrich their social networks, all of which are fundamental conditions for localized innovation and entrepreneurship (Ahmad et al., 2021; Zhang et al., 2023). The development of the rural digital economy is beneficial for stimulating farm households' willingness to engage in localized innovation and entrepreneurship (Yu et al., 2021; Deng et al., 2023; Chen, 2025). Based on this, we propose the following hypothesis.

> *Hypothesis 1*: Development of the rural digital economy directly stimulates farm households' willingness to innovate and start businesses, creating conditions for localized innovation and entrepreneurship and thereby benefiting rural industrial revitalization.

As the desire to innovate and start a business is not equivalent to actual entrepreneurial actions, farmers with entrepreneurial aspirations

may not always choose to innovate or start a business. This is because entrepreneurial actions are significantly influenced and constrained by various factors, such as the endowment variables of the household head, family, and region. Particularly for the household head, factors like educational background, work experience, financial advantage, and relevant training records could crucially impact the actualization of innovative entrepreneurship (Marchetta, 2012). Admittedly, impromptu innovation and entrepreneurship occur in certain scenarios, although these are relatively rare (Hu et al., 2023). Compared with the past, the rapid development of the rural digital economy has made innovation and entrepreneurship more convenient for farmers. Leveraging the unique advantages resulting from the development of the digital economy (such as information, financial, and network advantages), farmers now have the capacity and means to connect with the internet market (Su et al., 2021). Farmers engaged in traditional rural industries can rapidly initiate e-commerce businesses in agricultural products under the guidance of government policies that support and benefit agriculture, thereby creating conditions for the revitalization of local industries. Furthermore, leveraging the unique advantages of developing the digital economy, localized innovation, and entrepreneurship by farmers can help them transcend existing geographical limitations and engage in innovative activities while fully leveraging regional characteristics (Tang et al., 2022; Pan et al., 2024). For example, farmers engaged in agricultural e-commerce businesses can flexibly arrange the production and operation of agricultural products by obtaining sufficient production and marketing information, as well as a cross-regional organization of sources of agricultural products to ensure the smooth development of their own e-commerce business (Luo and Niu, 2019; Bhatia-Kalluri, 2021; Sánchez-Acevedo and Álvarez-Velásquez, 2023). In rural digital economy development, if farmers engage in e-commerce-related innovative entrepreneurship, they can conduct localized business operations by leveraging regional advantages without requiring traditional cash transactions (Bhatia-Kalluri, 2021; Guo et al., 2023; Nipo et al., 2024). In the context of the rural digital economy, transforming their entrepreneurial intentions into actions has become increasingly easy for farmers (Zhang and Wang, 2023; Wang and Liu, 2024; Pan et al., 2024). Based on this, we propose the following hypothesis.

> *Hypothesis 2*: Development of the rural digital economy directly impacts farmers' entrepreneurial actions, solidifying the foundation for localized innovation and entrepreneurship and benefiting rural industrial revitalization.

Since the initiation of economic reforms in 1978, the trajectory of rural entrepreneurship in China has evolved through three major stages: initial disengagement from agriculture (1978–1992), large-scale rural-to-urban migration (1992–2006), and a more recent trend of rural returnees initiating ventures in their hometowns (2007–present) (Li, 2013; Zhang and Song, 2003). In the earlier stages, limited access to productive resources, combined with underdeveloped infrastructure and institutional constraints in rural areas, contributed to the outflow of labor and entrepreneurial talent toward urban centers, where market size, industrial clusters, and knowledge spillovers offered more favorable conditions for business development (Zhao, 1999; Glaeser and Kerr, 2010; Duran, 2024). Urban agglomerations long enjoyed comparative advantages in attracting entrepreneurs due to access to capital, technology, and specialized labor networks (Florida, 2002; Qian et al., 2013; Audretsch and Belitski, 2017). In contrast, rural regions were constrained by resource scarcity and informational isolation, making even sustaining small-scale business activities, such as trading or family-run services, difficult (Cai et al., 2009; Zhu et al., 2019; Chen, 2025). Despite the higher cost of living, many rural entrepreneurs viewed cities as offering clearer pathways to expand business operations and gain economic traction (Li and Wu, 2018; Yu and Liu, 2022; Wang et al., 2024). However, with the advent of the digital economy, particularly the expansion of rural broadband infrastructure and the emergence of e-commerce platforms, a shift has begun to emerge. The longstanding urban–rural information gap is gradually diminishing, thereby enabling farmers to access real-time market data, digital payment systems, and remote logistics services that were previously unavailable (Wang et al., 2022; Wang H. et al., 2025). These changes have substantially lowered the threshold for initiating rural ventures and enhanced the feasibility of localized innovation and entrepreneurship. Through digital tools, rural residents can now more effectively integrate local agricultural products into value-added activities, establishing business models that reflect both ecological suitability and familial preferences (Hu et al., 2023; Lu et al., 2025; Wang and Wu, 2025). Furthermore, entrepreneurship rooted in local resource endowments, such as specialty farming or agritourism, offers flexible income opportunities while supporting rural industrial restructuring and diversification. Based on this, we propose the following hypothesis.

> *Hypothesis 3*: The development of the rural digital economy directly affects the profits of farmers' innovation and entrepreneurship, guarantees localized innovation and entrepreneurship, and is beneficial for rural industrial revitalization.

3 Materials and methods

3.1 Data source

This study used the geographical indication of navel oranges as a criterion for sample selection. The survey covers regions known for their navel orange production, including Jiangxi Province (mainly Xinfeng County, Xunwu County, Anyuan County, Huichang County, and Ruijin City, which are part of the Gannan navel orange production area), Sichuan Province (mainly in the counties of Linshui, Jintang, Leibo, Xichong and Yanbian, which are the production areas of Linshui, Jintang, Leibo, Xifeng, and Hongge navel oranges, respectively), Hunan Province (mainly Longshan County and Hongjiang City, which are the production areas of Liye and Qianyang Navel Oranges, respectively), Yichang City, Hubei Province (mainly Zigui County, the production area of Zigui navel oranges) and Chongqing Municipality (primarily Fengjie County, the production area of Fengjie navel oranges). In June 2023, the group conducted a questionnaire survey in these areas. In this survey, 90 questionnaires were randomly distributed to each sample unit, totaling 1,190 collected questionnaires. After excluding those with missing key information, 1,042 valid questionnaires remained, resulting in an effective rate of 82.70%.

3.2 Variable construction and definitions

This study's dependent variable is rural industrial revitalization. Rural industrial revitalization is frequently reflected in farmers' localized innovations and entrepreneurship (Peng et al., 2021). In areas with a positive rural industry development trend, the external environment for farmers' localized innovation and entrepreneurship is typically better (Gao and Liu, 2020; Li et al., 2025). A superior business environment directly stimulates farmers' willingness to engage in localized innovation and entrepreneurship and solidifies the foundation for transforming this willingness into action (Chen and Yang, 2024; Wang and Wu, 2025). It substantially increases the actual effectiveness of localized innovation and entrepreneurship among farmers (Liang and Qiao, 2025; Wang S. et al., 2025). Accordingly, this study measures rural industrial revitalization from three dimensions: willingness, action, and effectiveness. In the survey questionnaire, the questions closely related to these dimensions are as follows: "Assuming other factors are excluded, are you willing to innovate and start a business in your county (city)? A. Unwilling, and B. Willing;" "Assuming other factors are excluded, have you had any experience of innovating and starting a business in your county (city) from 2017 to the present? A. No, and B. Yes;" and "Assuming that other factors are excluded, how does the income earned from your innovation and entrepreneurship in your county (city) from 2017 to the present compare with your total household income? A. Very small proportion, B. Relatively small proportion, C. Average, D. Relatively large proportion, and E. Very large proportion."

This study's core explanatory variable is the development of a rural digital economy. Although no consensus exists on the construction of indicator systems for measuring the level of digital economy development, based on this study's practical needs, these systems can generally be categorized into hardware and software indicators (Bukht and Heeks, 2018; OECD, 2020; Liu et al., 2022; Guo et al., 2024). This study uses farmers' evaluations of the hardware and software aspects of the digital economy in their region to measure rural digital economic development (Zhang et al., 2024). The related questions in the survey questionnaire were as follows: "Excluding external factors, how satisfied are you with the level of the digital economy hardware infrastructure in your area? A. Very dissatisfied, B. Dissatisfied, C. Average, D. Satisfied, and E. Very satisfied;" and "Excluding external factors, how satisfied are you with the level of digital economy software infrastructure in your area? A. Very dissatisfied, B. Dissatisfied, C. Average, D. Satisfied, and E. Very satisfied."

Control variables are selected from three broad categories: endowment variables of the farm household head, farm household family endowment variables, and regional endowment variables (de Janvry and Sadoulet, 2001; Reardon et al., 2007; Davis et al., 2010). The rationale behind this choice is that farm households are the key agents of rural industrial revitalization (Zhang and Fan, 2004; Zhang et al., 2022). Through localized innovation and entrepreneurship, farm households not only create employment opportunities and facilitate the transfer of surplus rural labor but also directly promote the integration of the rural tertiary sector (Haggblade et al., 2010; Chen, 2025; Liu et al., 2021). This lays a solid foundation for the digital transformation of rural industries, thereby driving rural industrial revitalization and achieving common prosperity for both farmers and rural areas (Li et al., 2019; Gao and Liu, 2020). Furthermore, the success of farm households in localized innovation and entrepreneurship is significantly influenced by family dynamics (Kimhi, 2006; Doss, 2018). Undoubtedly, as a leader in rural industrial revitalization, the government plays a crucial role (Long et al., 2016; Liu and Li, 2017; Xu et al., 2018). Table 1 presents the specific indicators of these variables and their assigned values.

3.3 Reliability and validity tests

To enhance the scientific rigor and credibility of the survey data, a comprehensive assessment of the questionnaire's reliability and validity was conducted prior to the empirical analysis. In terms of reliability, internal consistency was evaluated using Cronbach's alpha for the scales associated with the study's key constructs. The results indicate that all primary scales achieved alpha coefficients above 0.70, suggesting acceptable to high internal reliability, aligning with established standards in social science research. Regarding validity, the evaluation was conducted from two perspectives: content and construct validity. To ensure content validity, the questionnaire items were developed based on an extensive review of literature relevant to the sampled regions, particularly documents issued by local agricultural authorities. Expert consultations were also incorporated during the questionnaire design process to ensure comprehensive coverage of the conceptual domains under investigation. To assess construct validity, exploratory factor analysis (EFA) was employed. The Kaiser-Meyer-Olkin (KMO) measure exceeded 0.70, and the Bartlett's test of sphericity was highly significant ($p < 0.01$), confirming the dataset's suitability for factor extraction. All factor loadings for the core items were above 0.50, supporting the presence of clear latent constructs with satisfactory convergent and discriminant validity. Taken together, the results confirm that the questionnaire data exhibit sound psychometric properties in terms of both reliability and validity, providing a robust foundation for subsequent empirical investigations.

3.4 Model specification

This study proposes establishing a baseline model to examine how the development of the rural digital economy promotes rural industrial revitalization:

$$Y_{iz} = \gamma_0 + \gamma_1\theta_n + \gamma_2 X_I + \gamma_3 X_{II} + \gamma_4 X_{III} + \varepsilon_i \quad (1)$$

In Equation (1), Y represents the revitalization of rural industries. i represents the ith sample. z represents three dimensions of rural industrial revitalization, and z takes the values 1, 2, and 3, which, respectively, represent rural industrial revitalization in the willingness dimension, rural industrial revitalization in the action dimension, and rural industrial revitalization in the effect dimension. γ is the parameter to be estimated. θ_n is a dummy variable. n takes the values 0 and 1, indicating the overall evaluation of the farm household regarding the development of the rural digital economy hardware and software aspects in the sample area. X_I, X_{II}, and X_{III} represent the three groups of control variables that affect rural industrial revitalization: household head, family, and regional endowment variables, respectively. ε is a random error term.

TABLE 1 Variable assignment and descriptive statistical analysis results.

Variable	Variable definition	Average	SD
Explained variable			
Willingness dimension of rural industry revitalization	Willingness for localized innovation and entrepreneurship: unwilling = 0, willing = 1	0.6715	0.0018
Action dimension rural industry revitalization	Localized innovation and Entrepreneurship Action: None = 0, Yes = 1	0.3612	0.1205
Effect dimension rural industry revitalization	The proportion is very small = 0, the proportion is relatively small = 1, the proportion is generally = 2, the proportion is relatively large = 3, and the proportion is very large = 4	0.1548	0.2311
Core explanatory variable			
Development of rural digital economy	Hardware: very dissatisfied = 0, dissatisfied = 1, average = 2, satisfied = 3, very satisfied = 4	2.3455	0.9333
	Software: very dissatisfied = 0, dissatisfied = 1, average = 2, satisfied = 3, very satisfied = 4	2.2601	1.1741
Household endowment variable			
Age (Age)	Actual age of head of household (years old)	40.0239	17.2328
Educational situation (Edu)	College and above = 0, high school, technical secondary school and technical school = 1, junior high school and below = 2	1.6094	0.5779
Marital status (Mar)	Unmarried = 0, married without spouse = 1, married with spouse = 2	1.7447	0.5911
Health condition (Hea)	Health satisfaction: dissatisfaction = 0, average = 1, satisfaction = 2	1.7044	0.6446
Political status (Pol)	Political outlook: party members = 0, democratic parties, independents and the masses = 1	0.9506	0.1017
Religious belief (Rel)	Religious belief: no religious belief = 0, religious belief = 1	0.1427	0.2026
Family endowment variable			
Family taboo types (Typ)	Part-time farmers = 0, non-part-time farmers = 1	0.6669	0.4713
Household income and expenditure (Hie)	Income and expenditure ratio < 1, income and expenditure ratio ≈ 1, income and expenditure ratio > 1	0.3715	0.4217
Number of family burden (Bur)	Number of people that need to be raised and supported by the family (person)	2.2219	0.3072
Family village representatives (Rep)	Does the family have villagers' representatives: Yes = 0, No = 1	0.8973	0.3035
Family farmland circulation (Cir)	Whether the family participates in rural land circulation: circulation = 0, non-circulation = 1	0.2495	0.4328
Volunteer service situation (Vol)	Whether the family has received voluntary service: Yes = 0, No = 1	0.1662	0.3686
Families join cooperatives (Coo)	Whether the family joins the farmers' professional cooperative: Yes = 0, No = 1	0.2457	0.4305
Regional endowment variable			
Financial literacy education (Fin)	Very satisfied = 0, satisfied = 1, average = 2, dissatisfied = 3, very dissatisfied = 4	2.9427	5.5621
Rural collective economy (Rce)	Very satisfied = 0, satisfied = 1, average = 2, dissatisfied = 3, very dissatisfied = 4	2.8526	0.1459
Regional public brand (Rpb)	Very satisfied = 0, satisfied = 1, average = 2, dissatisfied = 3, very dissatisfied = 4	2.0125	0.1021
Agricultural technical training (Agr)	Very satisfied = 0, satisfied = 1, average = 2, dissatisfied = 3, very dissatisfied = 4	2.3301	0.8365
Logistics service network (Log)	Very satisfied = 0, satisfied = 1, average = 2, dissatisfied = 3, very dissatisfied = 4	1.8810	1.0529
Rural basic education (Rbe)	Very satisfied = 0, satisfied = 1, average = 2, dissatisfied = 3, very dissatisfied = 4	1.5106	0.9108
Rural social security (Rsc)	Very satisfied = 0, satisfied = 1, average = 2, dissatisfied = 3, very dissatisfied = 4	2.0499	1.3250

4 Results

4.1 Baseline regression results

Since the dependent variable, "rural industrial revitalization," in this study is an unordered categorical variable, the study initially uses a logit and probit model. After conducting logistic distribution and normality tests, the probit model was more suitable for this study. Given that the sample size is 1,042, which exceeds 1,000, and considering that estimating the baseline model (1) set earlier is not for prediction, theoretically, the ordinary least squares (OLS) method could also be used for estimation. However, this occurs under the condition that Model (1) does not exhibit significant heteroscedasticity. Acknowledging the strengths and weaknesses of the different models and methods, this study uses both the ordered probit model and the OLS method to robustly and scientifically empirically test how the development of the rural digital economy promotes rural industrial revitalization. The empirical results indicate that, regardless of using the ordered probit model or OLS method, the coefficients of the core explanatory variable (levels of rural digital economy development) are identical regarding their signs and significance.

Before proceeding with the OLS estimation, we conducted a series of specification diagnostics on Model (1) to determine whether multicollinearity or heteroskedasticity posed significant issues. The

variance inflation factor (VIF) was calculated to be 3.1516, which is comfortably below the conventional threshold of 10, suggesting that multicollinearity is not a major concern. Furthermore, the *p*-value obtained from the White test was 0.6142, which exceeds the 5% level, indicating that the model does not suffer from heteroskedasticity. Nonetheless, the development of rural digital economies may be affected by unobserved regional factors such as economic infrastructure and digital receptiveness. These unobservable characteristics could also influence rural industrial outcomes, thereby introducing potential endogeneity into the model—most notably through omitted variable bias and possible reverse causality. To assess this concern, we applied the Durbin–Wu–Hausman (DWH) test to both the hardware and software dimensions of rural digital economy development. The results revealed statistically significant endogeneity, with test statistics of 3.9851 and 3.3618 and corresponding *p*-values of 0.0065 and 0.0083, respectively. To address these endogenous relationships, we employed an instrumental variable approach, using the two-stage least squares (2SLS) estimation method. Following previous literature (e.g., Zhang et al., 2019), we selected the spherical distance between each sampled prefecture-level city and Hangzhou—widely recognized as a digital innovation hub in China—as our instrument. Hangzhou, as the home of Alibaba, has taken a leading role in digital economic development, often exerting spatial spillover effects into nearby regions. Thus, proximity to Hangzhou can be expected to influence how local populations perceive access to digital infrastructure and services. With respect to the exclusion restriction, while geographic proximity to Hangzhou may have some indirect associations with regional digital development, we argue that it primarily affects residents' subjective perceptions, rather than exerting a direct influence on the actual advancement of local digital infrastructure. Once we account for regional fixed effects and other controls, no direct channel appears to link the instrument to the outcome variable, satisfying the conditions for instrument exogeneity. Finally, the strength and validity of the instrumental variable were evaluated using the Cragg–Donald Wald F-statistic and the Kleibergen–Paap rk LM test. The diagnostics confirm that the instrument is neither weak nor under-identified, reinforcing its appropriateness for addressing the endogeneity issue in this empirical context. The results are presented in Tables 2, 3.

From Tables 2, 3, the development of the rural digital economy, both in terms of hardware and software as evaluated by farmers, evidently effectively promotes rural industrial revitalization. Even after addressing endogeneity issues, the positive impact of the rural digital economy on rural industrial revitalization appears to have been further enhanced, thereby validating the research hypotheses. The reason for these findings is multifaceted: ease of localized innovation and entrepreneurship. The development of the rural digital economy, especially with the steady implementation of the digital village development strategy, has made localized innovation and entrepreneurship easier for farmers. Under the backdrop of the rural digital economy, farmers can quickly access external information, which helps resolve potential difficulties in the process of localized innovation and entrepreneurship, thus stimulating their willingness to engage in such activities. The author's field research found that, with the opportunity to develop a rural digital economy, some farmers, through a comprehensive and systematic understanding of rural e-commerce development, may be based on the reality of innovation and entrepreneurship.

Furthermore, information technology expands the horizons of farmers, effectively stimulating their willingness to innovate and start businesses, thereby laying a solid foundation for rural industrial revitalization. However, with the development of the rural digital economy, farmers' willingness to localize their innovation and entrepreneurship can be transformed into innovation and entrepreneurship actions more quickly. By leveraging the unique advantages of the rural digital economy, many practical issues encountered in the process of localized innovation and entrepreneurship can be resolved promptly, thereby accelerating the transformation of farmers' willingness to localize innovation and entrepreneurship into innovation and entrepreneurial action. Compared with the past, the rapid development of the rural digital economy helps entrepreneurial farmers stay informed about various agricultural policies, reduces unnecessary credit approval processes, and facilitates access to urgently needed working capital from financial institutions. It also enables farmers to expand their businesses online in a production-supply-sales-integrated manner. In the short term, this positively impacts and accelerates the digital transformation of rural industries; in the long term, it undoubtedly contributes to rural industrial revitalization. Additionally, the development of the rural digital economy can, to a large extent, directly increase the economic benefits of localized innovation and entrepreneurship for farmers. In the past, the development of rural industries was largely constrained by geographical limitations and relied on cash-and-carry trade methods. However, with the advent of the rural digital economy, the development of rural industries is no longer restricted by location, transaction costs are significantly reduced, and the effectiveness of localized innovation and entrepreneurship is more apparent. As a result, the rural digital economy provides a strong foundation for rural industrial revitalization (Tian et al., 2023).

4.2 Robustness checks

To validate the robustness of the main findings, we further disaggregate the sample by respondents' ethnic background and conduct separate regressions for Han and minority households. The results, presented in Table 4, indicate that the rural digital economy plays a positive and statistically significant role in promoting rural industrial revitalization in both groups. This supports the reliability and consistency of the baseline conclusions. Moreover, the effect appears stronger in the action-oriented dimension among minority respondents, which may be linked to differences in access to digital infrastructure or variations in local organizational structures during the adoption of digital technologies in rural areas.

To ensure the robustness of the main findings, we removed households with annual incomes in the highest and lowest 5 percent of the sample and re-estimated the model using the adjusted dataset. The results, presented in Table 5, show that the positive relationship between rural digital economy development and rural industrial revitalization remains statistically significant. Moreover, the direction and magnitude of the estimates are consistent with the baseline regression, indicating that the core conclusions hold even when excluding extreme income values. This suggests that the analysis is not overly sensitive to sample composition and that the results are both stable and reliable across subsample conditions.

TABLE 2 Benchmark regression results at the hardware evaluation level of farmers.

	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Hardware	0.2219*** (0.0456)	0.2107*** (0.0467)	0.1985*** (0.0721)	0.1801*** (0.0827)	0.2201*** (0.0225)	0.2101*** (0.0628)
Age	−0.1146*** (0.0138)	−0.1265*** (0.0526)	−0.1049** (0.0267)	−0.1126*** (0.0462)	−0.1267*** (0.0451)	−0.1346*** (0.0326)
Edu	−0.1673*** (0.0517)	−0.1702** (0.0726)	−0.1549*** (0.0426)	−0.1621*** (0.0605)	−0.1352*** (0.0248)	−0.1402** (0.0465)
Mar	0.1136*** (0.0048)	0.1016** (0.0386)	0.1302*** (0.0146)	0.1227*** (0.0127)	0.1402*** (0.0227)	0.1341** (0.0446)
Hea	0.1422** (0.0261)	0.1307*** (0.0352)	0.1246** (0.0226)	0.1108*** (0.0426)	0.1337*** (0.0302)	0.1205*** (0.0201)
Pol	−0.1126*** (0.0427)	−0.1238** (0.0327)	−0.1302*** (0.0401)	−0.1447*** (0.0328)	−0.1222*** (0.0015)	−0.1326*** (0.0213)
Rel	0.1516 (0.1985)	0.1825 (0.4206)	0.1422 (0.2027)	0.1301 (0.1015)	0.1615 (0.1102)	0.1709 (0.2026)
Typ	−0.1226*** (0.0427)	−0.1332*** (0.0328)	−0.1521*** (0.0421)	−0.1658*** (0.0723)	−0.1048*** (0.0146)	−0.1127*** (0.0028)
Hie	0.1423*** (0.0415)	0.1306*** (0.0021)	0.1222*** (0.0317)	0.1101*** (0.0086)	0.1301*** (0.0029)	0.1225*** (0.0446)
Bur	−0.1311** (0.0126)	−0.1428*** (0.0552)	−0.1247*** (0.0421)	−0.1306** (0.0529)	−0.1146*** (0.0327)	−0.1203*** (0.0156)
Rep	−0.1301** (0.0712)	−0.1426** (0.0417)	−0.1507*** (0.0126)	−0.1604*** (0.0428)	−0.1421*** (0.0321)	−0.1526*** (0.0145)
Cir	−0.1405*** (0.0095)	−0.1568*** (0.0201)	−0.1326*** (0.0449)	−0.1436*** (0.0336)	−0.1206*** (0.0426)	−0.1326*** (0.0601)
Vol	−0.1612*** (0.0736)	−0.1728** (0.0068)	−0.1435*** (0.0529)	−0.1526*** (0.0027)	−0.1426*** (0.0125)	−0.1526*** (0.0201)
Coo	−0.1721*** (0.0575)	−0.1861*** (0.0826)	−0.1601*** (0.0727)	−0.1736** (0.0081)	−0.1501*** (0.0626)	−0.1627*** (0.0525)
Fin	−0.1516*** (0.0671)	−0.1625*** (0.0459)	−0.1426*** (0.0146)	−0.1509** (0.0521)	−0.1302*** (0.0625)	−0.1427*** (0.0621)
Rce	−0.1436** (0.0205)	−0.1532** (0.0028)	−0.1323*** (0.0046)	−0.1425*** (0.0527)	−0.1201*** (0.0427)	−0.1347*** (0.0324)
Rpb	−0.1367*** (0.0626)	−0.1446*** (0.0327)	−0.1222*** (0.0428)	−0.1335*** (0.0378)	−0.1148*** (0.0201)	−0.1206*** (0.0337)
Agr	−0.1417*** (0.0426)	−0.1527*** (0.0228)	−0.1332*** (0.0147)	−0.1426*** (0.0412)	−0.1226*** (0.0201)	−0.1347*** (0.0325)
Log	−0.1512*** (0.0427)	−0.1702** (0.0826)	−0.1601*** (0.0567)	−0.1726*** (0.1307)	−0.1426*** (0.0521)	−0.1502** (0.0629)
Rbe	−0.1302*** (0.0461)	−0.1421*** (0.0622)	−0.1202** (0.0547)	−0.1311*** (0.0157)	−0.1148*** (0.0326)	−0.1205*** (0.0452)
Rsc	−0.1425*** (0.0376)	−0.1569*** (0.0146)	−0.1236*** (0.0281)	−0.1141*** (0.0356)	−0.1326*** (0.0475)	−0.1402*** (0.0328)
R^2	0.1423	0.1541	0.1307	0.1467	0.1326	0.1498
F statistics	26.2637	59.6321	22.2369	95.2301	42.2657	86.2617

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors are shown in parentheses. (1), (2), and (3) respectively refer to the willingness dimension of rural industry revitalization, the action dimension of rural industry revitalization, and the effect dimension of rural industry revitalization. The models have controlled regional effects.

4.3 Heterogeneity test

First, it examines the heterogeneity in how the development of the rural digital economy promotes rural industrial revitalization from different business perspectives. The study sample comprised farmers involved in producing and selling navel oranges with geographical indications. These farmers are part-time and specialized farmers. This study categorizes households solely engaged in navel orange cultivation as specialized farmers. In contrast, those engaged in other industries besides navel orange cultivation are categorized as part-time farmers. In the empirical analysis, specialized farmers are assigned a value of 1, while part-time farmers have a value of 0. The empirical results shown in Table 6 reveal significant heterogeneity in the impact of the rural digital economy on rural industrial revitalization. From the hardware perspective, the rural digital economy's development did not significantly impact navel orange farmers across different business types. However, from the software perspective, this effect is significant.

Second, the heterogeneity of rural digital economic development for rural industrial revitalization is based on different scales. This study adopts the standard from the "Third National Agricultural Census Scheme" in China, which considers farmers with a land area of 100 mu (approximately 6.67 hectares) or more under a single cropping system as large-scale farmers. Based on this criterion, the sample is roughly divided into large-scale navel orange production and marketing farmers and non-large-scale production and marketing farmers. In the empirical analysis, large-scale production and marketing farmers are assigned a value of 1, while non-large-scale production and marketing farmers are assigned a value of 0. The empirical results, shown in Table 7, reveal significant heterogeneity in the impact of rural digital economy development on rural industrial revitalization. At both the hardware and software levels, the impact of rural digital economy development on the willingness of navel orange production and marketing farmers of different sizes to engage in innovation and entrepreneurship was not significant. Conversely, the impact on the actions and effects of the willingness of navel orange production and marketing farmers of different sizes to engage in innovation and entrepreneurship was significant.

4.4 Mechanism analysis

How can rural digital economic development contribute to the revitalization of rural industries? From a practical perspective,

TABLE 3 Benchmark regression results at the software evaluation level of farmers.

	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Software	0.2015*** (0.0102)	0.1951*** (0.0223)	0.2102*** (0.0745)	0.2005*** (0.0159)	0.2201*** (0.0645)	0.2146*** (0.0829)
Age	−0.1205** (0.0527)	−0.1365*** (0.0625)	−0.1401*** (0.0568)	−0.1552*** (0.0425)	−0.1325*** (0.0452)	−0.1402*** (0.0502)
Edu	−0.1625*** (0.0041)	−0.1731*** (0.0626)	−0.1521*** (0.0257)	−0.1647*** (0.0126)	−0.1501*** (0.0547)	−0.1638*** (0.0526)
Mar	0.1301*** (0.0352)	0.1226*** (0.0426)	0.1102** (0.0437)	0.1041*** (0.0225)	0.1221*** (0.0627)	0.1142*** (0.0201)
Hea	0.1206*** (0.0427)	0.1101*** (0.0326)	0.1307*** (0.0272)	0.1203*** (0.0348)	0.1145*** (0.0201)	0.1036*** (0.0145)
Pol	−0.1336*** (0.0007)	−0.1446*** (0.0026)	−0.1125*** (0.0137)	−0.1236*** (0.0048)	−0.1204*** (0.0201)	−0.1326*** (0.0148)
Rel	0.1509 (0.0102)	0.1609 (0.0213)	0.1701 (0.0328)	0.1567 (0.0301)	0.1425 (0.0227)	0.1501 (0.0216)
Typ	−0.1202*** (0.0332)	−0.1337*** (0.0415)	−0.1124*** (0.0327)	−0.1235** (0.0092)	−0.1326*** (0.0201)	−0.1421*** (0.0368)
Hie	0.1301*** (0.0451)	0.1201* (0.0428)	0.1148*** (0.0315)	0.1011*** (0.0292)	0.1202*** (0.0107)	0.1346*** (0.0206)
Bur	−0.1107*** (0.0326)	−0.1267*** (0.0148)	−0.1426*** (0.0327)	−0.1567*** (0.0146)	−0.1202*** (0.0201)	−0.1301*** (0.0527)
Rep	−0.1335** (0.0426)	−0.1402* (0.0275)	−0.1206*** (0.0359)	−0.1336*** (0.0247)	−0.1125*** (0.0185)	−0.1202*** (0.0254)
Cir	−0.1205*** (0.0201)	−0.1342*** (0.0072)	−0.1406*** (0.0426)	−0.1568*** (0.0127)	−0.1324*** (0.0025)	−0.1406*** (0.0029)
Vol	−0.1526*** (0.0125)	−0.1622** (0.0147)	−0.1324** (0.0417)	−0.1421*** (0.0162)	−0.1225*** (0.0225)	−0.1368*** (0.0301)
Coo	−0.1402*** (0.0067)	−0.1536** (0.0132)	−0.1369*** (0.0021)	−0.1436*** (0.0027)	−0.1204*** (0.0121)	−0.1307*** (0.0201)
Fin	−0.1511*** (0.0046)	−0.1721** (0.0016)	−0.1421*** (0.0037)	−0.1526*** (0.0552)	−0.1326*** (0.0002)	−0.1402** (0.0026)
Rce	−0.1407** (0.0329)	−0.1568** (0.0045)	−0.1326*** (0.0026)	−0.1426*** (0.0512)	−0.1206** (0.0227)	−0.1308*** (0.0027)
Rpb	−0.1502*** (0.0098)	−0.1612*** (0.0201)	−0.1426*** (0.0147)	−0.1547*** (0.0021)	−0.1205*** (0.0048)	−0.1336** (0.0226)
Agr	−0.1328*** (0.0435)	−0.1425*** (0.0167)	−0.1316*** (0.0025)	−0.1236*** (0.0501)	−0.1057*** (0.0027)	−0.1148*** (0.0167)
Log	−0.1462** (0.0328)	−0.1502*** (0.0125)	−0.1306*** (0.0526)	−0.1427*** (0.0682)	−0.1121*** (0.0501)	−0.1229*** (0.0472)
Rbe	−0.1336*** (0.0012)	−0.1425*** (0.0026)	−0.1207*** (0.0027)	−0.1326*** (0.0028)	−0.1146*** (0.0201)	−0.1236*** (0.0149)
Rsc	−0.1519** (0.0217)	−0.1637*** (0.5012)	−0.1424*** (0.0022)	−0.1526*** (0.0127)	−0.1325*** (0.0028)	−0.1402*** (0.0646)
R^2	0.1427	0.1526	0.1302	0.1462	0.1298	0.1356
F statistics	23.3265	67.5621	20.2326	82.2307	31.2307	125.2301

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors are shown in parentheses. (1), (2), and (3) respectively refer to the willingness dimension of rural industry revitalization, the action dimension of rural industry revitalization, and the effect dimension of rural industry revitalization. The models have controlled regional effects.

developing a rural digital economy promotes the revitalization of rural industries mainly through three channels: employment, income generation, and happiness effects. From the perspective of the employment effect, research indicates that the development of the digital economy significantly reduced the likelihood of underemployment (Wang and Shao, 2023). Compared with the past, surplus rural labor can not only find new job opportunities in the digital transformation of rural industries but also better development opportunities in emerging rural industries, all of which are conducive to promoting rural industrial revitalization. From the perspective of income-generating effects, Peng and Dan (2023) show that the digital transformation of rural industries has accelerated the development of the rural digital economy, leading to a steady increase in farmers' income. Naturally, this increase in income solidifies the economic foundation of rural industrial revitalization. According to Meng and Xiao (2023), developing a rural digital economy enhances residents' happiness by improving efficiency and promoting fairness. As one of the main objectives of rural revitalization, enhancing residents' happiness is conducive to promoting rural industrial revitalization.

The three questions in the questionnaire that are closely related to the mechanism test are: "Ignoring other factors, what kind of impact do you think the development of the digital economy in your area has had on employment among your surrounding community? A. Almost no impact, B. Very little impact, C. Average impact, D. Significant impact, and E. Very significant impact," "Ignoring other factors, what impact do you think the development of the digital economy in your area has had on the household income of your surrounding community? A. Almost no impact, B. Very little impact, C. Average impact, D. Significant impact, and E. Very significant impact;" and "Ignoring other factors, what kind of impact do you think the development of the digital economy in your area has had on the happiness of your surrounding community? A. Almost no impact, B. Very little impact, C. Average impact, D. Significant impact, and E. Very significant impact."

In the empirical analysis, this study uses responses to these questions as dependent variables for Model (1) to examine the mechanisms through which the development of the rural digital economy promotes rural industrial revitalization. The results, presented in Tables 8, 9, show that the employment, income enhancement, and happiness effects of the rural digital economy's development are all highly significant, whether from a hardware or software perspective.

TABLE 4 Regression results by ethnic group.

Farmers' hardware evaluation level (Han household head sample)						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Hardware	0.2216*** (0.0026)	0.2047*** (0.0001)	0.2156*** (0.0065)	0.2001*** (0.0027)	0.2319*** (0.0098)	0.2211*** (0.0012)
R^2	0.1722	0.1801	0.1698	0.1725	0.1669	0.1736
F statistics	14.5601	26.2329	11.2517	33.3219	20.0269	75.5629

Farmer's software evaluation level (Han household head sample)						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Software	0.2112*** (0.0025)	0.2003*** (0.0021)	0.2221*** (0.0069)	0.2154*** (0.0001)	0.2306*** (0.0009)	0.2117*** (0.0076)
R^2	0.1852	0.1722	0.1345	0.1267	0.1311	0.1402
F statistics	14.2635	29.0237	18.2501	45.5601	30.0367	56.6219

Farmers' hardware evaluation level (Ethnic minority household head sample)						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Hardware	0.1998*** (0.0081)	0.1806*** (0.0063)	0.3325*** (0.0001)	0.3145*** (0.0007)	0.2201*** (0.0041)	0.1925*** (0.0039)
R^2	0.1116	0.1852	0.1415	0.1502	0.1419	0.1536
F statistics	20.2307	69.2601	15.2501	46.2625	20.2159	65.2617

Farmer's software evaluation level (Ethnic minority household head sample)						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Software	0.2147*** (0.0012)	0.2002*** (0.0001)	0.3215*** (0.0025)	0.3212*** (0.0068)	0.2215*** (0.0047)	0.2103*** (0.0051)
R^2	0.1311	0.1215	0.1207	0.1311	0.1212	0.1307
F statistics	25.2301	39.2601	45.2518	98.2501	12.2328	38.1205

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors are shown in parentheses. (1), (2), and (3) respectively refer to the willingness dimension of rural industry revitalization, the action dimension of rural industry revitalization, and the effect dimension of rural industry revitalization. The models have controlled regional effects.

TABLE 5 Robustness results after trimming income extremes.

Farmers' hardware evaluation level						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Hardware	0.2213*** (0.0012)	0.2114*** (0.0011)	0.2346*** (0.006)	0.2211*** (0.0046)	0.2201*** (0.0057)	0.2105*** (0.0098)
R^2	0.1355	0.1426	0.1145	0.1276	0.1367	0.1411
F statistics	20.2305	68.6201	16.2601	45.2632	30.0326	90.6257

Farmer's software evaluation level						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Software	0.2256*** (0.0011)	0.2092*** (0.0317)	0.2211*** (0.0001)	0.2142*** (0.0021)	0.2332*** (0.0006)	0.2202*** (0.0007)
R^2	0.1256	0.1158	0.1342	0.1401	0.1145	0.1227
F statistics	14.5201	36.6207	20.3327	45.2516	33.3611	56.6207

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors are shown in parentheses. (1), (2), and (3) respectively refer to the willingness dimension of rural industry revitalization, the action dimension of rural industry revitalization, and the effect dimension of rural industry revitalization. The models have controlled regional effects.

TABLE 6 Heterogeneity regression results from the perspective of different formats.

Farmers' hardware evaluation level						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Hardware	0.2512 (0.3981)	0.2216 (0.1963)	0.2413 (0.2201)	0.2601 (0.4527)	0.2007 (0.2398)	0.2126 (0.9512)
R^2	0.0751	0.1106	0.1301	0.1209	0.1308	0.1436
F statistics	12.2021	38.2305	6.0217	26.3212	22.2307	40.0129

Farmer's software evaluation level						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Software	0.2201*** (0.0075)	0.2101*** (0.0426)	0.2307*** (0.0501)	0.2216*** (0.0421)	0.2107*** (0.0362)	0.2019*** (0.0427)
R^2	0.1202	0.1346	0.1307	0.1435	0.1407	0.1552
F statistics	28.6217	59.2621	30.2307	78.5621	25.2617	75.2686

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors are shown in parentheses. (1), (2), and (3) respectively refer to the willingness dimension of rural industry revitalization, the action dimension of rural industry revitalization, and the effect dimension of rural industry revitalization. The models have controlled regional effects.

TABLE 7 Heterogeneous regression results from different scale perspectives.

Farmers' hardware evaluation level						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Hardware	0.2443 (0.3913)	0.2301 (0.2817)	0.2216*** (0.0825)	0.2101*** (0.0062)	0.2301*** (0.0412)	0.2216*** (0.0201)
R^2	0.0985	0.1001	0.1127	0.1298	0.1302	0.1445
F statistics	28.2621	45.2501	34.0217	90.2307	42.0217	88.5628

Farmer's software evaluation level						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Software	0.2029 (0.5542)	0.2226 (0.4761)	0.2201*** (0.0325)	0.2106*** (0.0025)	0.2016*** (0.0017)	0.1985*** (0.0552)
R^2	0.0715	0.0942	0.1115	0.1246	0.1307	0.1429
F statistics	24.2415	40.0267	30.0327	59.5921	40.0215	110.0217

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors are shown in parentheses. (1), (2), and (3) respectively refer to the willingness dimension of rural industry revitalization, the action dimension of rural industry revitalization, and the effect dimension of rural industry revitalization. The models have controlled regional effects.

5 Conclusion, policy implications, and research limitations

5.1 Conclusion

This study focuses on whether and how the development of the rural digital economy promotes rural industrial revitalization and engages in both theoretical and empirical analyses. Theoretically, the development of the rural digital economy impacts farmers' localized innovation and entrepreneurship across three dimensions—willingness, action, and effectiveness—thereby fostering rural industrial revitalization. Empirically, this study finds that both the hardware and software aspects of rural digital economy development significantly and positively affect the willingness, action, and effectiveness dimensions of rural industrial revitalization. This effect remains significant and even more pronounced after addressing endogeneity concerns. The impact of the rural digital economy's development on navel orange production and marketing across different business types is not significant from a hardware perspective. Conversely, from a software perspective, it is. Moreover, regardless of whether hardware or software aspects are considered, the impact of the rural digital economy's development on the innovation and entrepreneurship willingness of navel orange production and marketing farmers is not significant across different scales of operations; however, its impact on actions and outcomes is significant. This finding suggests heterogeneity in how the rural digital economy promotes rural industrial revitalization across different business types and scales. The development of the rural digital economy promotes rural industrial revitalization primarily through three channels: employment, income enhancement, and happiness effects.

5.2 Policy implications

The policy implications embedded in the findings of this study are as follows. First, rural industrial revitalization must emphasize the development of the rural digital economy. To compensate for the shortcomings in the construction of rural information infrastructure in the central and western regions, it is necessary to steadily push forward the optimization and upgrading of rural information infrastructure and ensure that 5G and gigabit fiber networks cover a more comprehensive range of villages. Leveraging the opportunity presented by the "Digital Village Development Action Plan (2022–2025)" to steadily promote the digital transformation of traditional rural infrastructure is necessary, laying the foundation for "agricultural products entering cities and industrial products reaching villages." The application of big data and information technology in agriculture should be prioritized to drive technological innovation in smart farming. Advancing the digital transformation of the entire agricultural production and operation process will provide strong support for the revitalization of rural industries. Overall, this means that great importance should be attached to the construction of hardware and software for the development of the rural digital economy to accelerate the pace of digital transformation of rural industries by comprehensively upgrading the development level of the rural digital economy, creating conditions for the in-depth application of new digital technologies in the integration of production-supply-marketing of all agricultural products, including navel oranges, and promoting the revitalization of rural industries.

Second, efforts from other aspects are necessary to promote the revitalization of rural industries. At the household head level, comprehensively improving the overall quality of individuals is necessary, not only in terms of their professional skills but also in terms of their digital literacy. To establish a correct view of marriage, reduce or eliminate the phenomenon of individual innovation and entrepreneurship affected by marriage problems; to establish a scientific view of health, pay attention to personal health while effectively providing healthy goods or services for the market. At the household level, it is necessary to create conditions to realize the flexible conversion between part-time and professional businesses, arrange the family's production and operation activities with the primary goal of maximizing the family's economic interests and actively participating in the revitalization of rural industries without violating national laws and regulations, and create conditions for the family to obtain better economic benefits from the revitalization of rural industries by optimizing the family's income and expenditure structure, transferring the surplus labor force, participating in the transfer of land, accepting volunteer services, joining farmers' professional cooperatives, and so on. Simultaneously, by optimizing the family income and expenditure structure, transferring surplus labor, participating in land transfer, receiving volunteer services, joining professional farmers' cooperatives, etc., we can do everything possible to create conditions for families to better obtain economic benefits from revitalizing rural industries. At the regional level, improving financial literacy among residents, tapping into the potential of the rural collective economy, cultivating regional public brands for agricultural products, strengthening agricultural technical training, optimizing logistics service network layouts, enhancing the level of basic rural education, and continuously improving the efficiency of

TABLE 8 Test results of the mechanism at the hardware evaluation level of farmers.

Farmers' employment effect						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Hardware	0.1865*** (0.0125)	0.1763*** (0.0205)	0.1702*** (0.0101)	0.1628*** (0.0401)	0.2021*** (0.0128)	0.1986*** (0.0526)
R^2	0.1226	0.1347	0.1148	0.1298	0.1332	0.1485
F statistics	29.3621	50.0217	30.0237	56.2601	45.0217	96.2601
Farmers' income increase effect						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Hardware	0.1975*** (0.0206)	0.1867*** (0.0305)	0.2102*** (0.0201)	0.2007*** (0.0785)	0.1862*** (0.0107)	0.1768*** (0.0025)
R^2	0.1201	0.1347	0.1148	0.1256	0.1338	0.1402
F statistics	30.2307	66.2342	26.2601	59.5217	22.2317	67.2615
Farmers' happiness effect						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Hardware	0.1875*** (0.0125)	0.1724*** (0.0206)	0.1976*** (0.0425)	0.1821*** (0.0301)	0.2021*** (0.0402)	0.1968*** (0.0562)
R^2	0.1268	0.1349	0.1145	0.1236	0.1302	0.1467
F statistics	27.5871	55.0219	22.2361	96.2627	45.0211	122.3209

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors are shown in parentheses. (1), (2), and (3) respectively refer to the willingness dimension of rural industry revitalization, the action dimension of rural industry revitalization, and the effect dimension of rural industry revitalization. The models have controlled regional effects.

TABLE 9 Test results of the mechanism at the software evaluation level of farmers.

Farmers' employment effect						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Software	0.2521*** (0.0025)	0.2402*** (0.0427)	0.2301*** (0.0016)	0.2216*** (0.0025)	0.2126*** (0.0425)	0.2069*** (0.0302)
R^2	0.1265	0.1325	0.1125	0.1206	0.1356	0.1427
F statistics	27.2651	50.0217	22.0217	62.0212	35.0517	125.0216
Farmers' income increase effect						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Software	0.2215*** (0.0425)	0.2111*** (0.0326)	0.2049*** (0.0104)	0.1986*** (0.0217)	0.1981*** (0.0478)	0.1862*** (0.0572)
R^2	0.1306	0.1405	0.1145	0.1202	0.1245	0.1326
F statistics	20.0217	70.0267	35.2621	90.0201	42.0217	159.2601
Farmers' happiness effect						
	(1)		(2)		(3)	
	OLS	2SLS	OLS	2SLS	OLS	2SLS
Software	0.2301*** (0.0892)	0.2217*** (0.0625)	0.2145*** (0.0207)	0.2001*** (0.0785)	0.1967*** (0.0416)	0.1863*** (0.0021)
R^2	0.1307	0.1426	0.1201	0.1335	0.1421	0.1369
F statistics	39.3621	78.2601	25.2621	70.0216	42.0217	185.2621

***$p < 0.01$, **$p < 0.05$, *$p < 0.1$. Robust standard errors are shown in parentheses. (1), (2), and (3) respectively refer to the willingness dimension of rural industry revitalization, the action dimension of rural industry revitalization, and the effect dimension of rural industry revitalization. The models have controlled regional effects.

rural social security to create a favorable external environment for regional rural industrial revitalization.

5.3 Research limitations

Despite drawing on a dataset comprising 1,042 survey responses from a representative navel orange-producing region and employing both ordered probit and OLS estimation techniques, this study has several limitations that warrant acknowledgment. While efforts were made to address potential endogeneity, certain constraints remain.

First, due to practical limitations related to data collection and survey administration costs, the sample is geographically concentrated and limited to a single agricultural product. As such, the generalizability of the findings to other crops or regional contexts may be restricted. Second, the construction of core explanatory variables relies primarily on farmers' subjective perceptions of digital economy development. Although internal consistency and validity checks were conducted and endogeneity was addressed through instrumental variable approaches, self-reported data may still be subject to response bias. Third, while the study differentiates between hardware and software components of the rural digital economy, it does not fully explore their interactions or how broader institutional factors shape their effectiveness.

Future research could improve upon these limitations in several ways. Expanding the sample to encompass multiple agricultural sectors and diverse geographic settings would enhance the external validity of the results. Longitudinal or experimental designs may also be employed to capture the evolving impact of digital infrastructure and services over time. Incorporating objective measures—such as broadband penetration rates, digital device usage logs, or mobile signal coverage—could further substantiate the empirical findings. Finally, exploring the role of policy implementation, governance structures, and region-specific institutional arrangements could provide deeper insights into how digital technologies become embedded within rural industrial systems, ultimately advancing more sustainable and inclusive models of rural revitalization.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Author contributions

ZL: Formal analysis, Writing – review & editing, Supervision, Writing – original draft, Funding acquisition, Conceptualization. LY: Formal analysis, Writing – original draft, Investigation, Software, Data curation, Writing – review & editing. DG: Writing – review & editing, Investigation, Formal analysis, Conceptualization, Methodology, Data curation. ZW: Writing – review & editing, Formal analysis, Software, Data curation, Investigation.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

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