



OPEN ACCESS

EDITED BY

Siphe Zantsi,
Agricultural Research Council of South Africa
(ARC-SA), South Africa

REVIEWED BY

Jan Swanepoel,
University of the Free State, South Africa
Walter Shiba,
Agricultural Research Council of South Africa
(ARC-SA), South Africa

*CORRESPONDENCE

Anis Amira Ab Rahman
✉ anisamira@umk.edu.my

RECEIVED 04 July 2025

REVISED 16 December 2025

ACCEPTED 19 December 2025

PUBLISHED 15 January 2026

CITATION

Peng J, Tu J, Niu M and Ab Rahman AA (2026)
How does rural digitalization contribute to
agricultural economic development? A
quasi-experiment with China's digital village
policy.
Front. Sustain. Food Syst. 9:1659472.
doi: 10.3389/fsufs.2025.1659472

COPYRIGHT

© 2026 Peng, Tu, Niu and Ab Rahman. This is
an open-access article distributed under the
terms of the [Creative Commons Attribution
License \(CC BY\)](https://creativecommons.org/licenses/by/4.0/). The use, distribution or
reproduction in other forums is permitted,
provided the original author(s) and the
copyright owner(s) are credited and that the
original publication in this journal is cited, in
accordance with accepted academic
practice. No use, distribution or reproduction
is permitted which does not comply with
these terms.

How does rural digitalization contribute to agricultural economic development? A quasi-experiment with China's digital village policy

Jiangqin Peng^{1,2}, Jian Tu¹, Mingzhen Niu³ and
Anis Amira Ab Rahman^{2*}

¹Business School, Jiangxi Institute of Fashion Technology, Nanchang, China, ²Faculty of Entrepreneurship and Business, Universiti Malaysia Kelantan, Kota Bharu, Malaysia, ³School of Economics & Management, Nanchang University, Nanchang, China

Introduction: The digital infrastructure gap in rural areas hinders the agricultural sectors of developing countries from harnessing the benefits of digital technologies. This study examines how rural digitalization, specifically through China's Digital Village Policy, contributes to agricultural economic development, addressing its roles and underlying mechanisms.

Methods: Utilizing panel data from county-level areas in China from 2011 to 2022, this research employs a quasi-experimental design and the difference-in-differences (DID) method to estimate the causal impact of digital village policies. Robustness tests, including parallel trend tests, placebo tests, propensity score matching (PSM-DID), and controls for other intrusive policies, are conducted to validate the findings.

Results: The results indicate that rural digitalization significantly promotes agricultural economic development, a finding that remains robust across various model specifications and tests. Heterogeneity analysis reveals that the policy effect is strongest in western China. Mechanism analysis further identifies three key transmission channels: enhancing agricultural productivity, accelerating the urbanization process, and strengthening county-level innovation capacity.

Discussion: These findings demonstrate that digital village construction drives agricultural economic growth through multifaceted pathways. The study provides theoretical insights into the synergistic effects of digitalization, institutional innovation, and spatial governance. It offers practical policy implications for optimizing smart agriculture initiatives and digital village strategies, both in China and for other developing regions aiming to achieve sustainable agricultural transformation.

KEYWORDS

agricultural economic, agricultural productivity, digital village policy, innovation capacity, rural digitalization, urbanization

1 Introduction

In the process of global agricultural transformation, slow technological innovation in production and asymmetric market information constitute a double structural dilemma that constrains sustainable development. This challenge directly threatens the achievement of two of the core objectives of the United Nations' Sustainable Development Goals (SDGs): one

challenge is the specific requirement in SDG 2 (Zero Hunger) to “double smallholder agricultural productivity and incomes by 2030” (Target 2.3), and the other challenge is the fundamental commitment in SDG 1 (Poverty Eradication) to “ensure that the poor have access to economic resources and technology” (Target 1.4). The innovative application of digital technologies provides a transformation path to overcome this dilemma by reconstructing the agricultural production function and market transaction mechanism. However, the scale of the digital divide in rural China remains substantial. For instance, in 2022, the urban internet penetration rate stood at 79.6%, compared to only 58.8% in rural areas (CNNIC, 2023). This gap is further exacerbated by pronounced regional disparities. Broadband access rates in western rural regions are merely 60% of those in the eastern provinces, reflecting a stark “digital gradient” from coast to interior (MIIT, 2023).

Prior policy efforts, while increasing infrastructure investment, have sometimes struggled to achieve transformative impact due to fragmented implementation, low digital literacy among farmers, and a disconnect between technology supply and local agricultural needs. This has led to a concerning shift from an ‘access divide’ to a ‘usage-and-impact divide’ in some regions. China’s “digital infrastructure–service platform–governance system” model promotes the coordinated advancement of institutional innovation and technological empowerment, demonstrating a creative approach to modern governance. Not only has this significantly advanced the digital transformation of county agriculture, but it also provides a replicable policy paradigm for the Global South to achieve the SDGs by increasing the productivity of smallholder farmers (SDG 2.3) and promoting the inclusion of technology (SDG 1.4). Through systematically examining this program in China, this study aims to reveal the internal mechanisms of agricultural modernization and transformation in the digital age, and to contribute new theoretical insights and practical solutions to achieve the agricultural Sustainable Development Goals at the global scale.

The digital economy enhances global agricultural quality and exhibits positive spatial autocorrelation (Song Y. et al., 2025). As a significant initiative for deeply integrating the digital economy with rural revitalization strategies, the digital village policy represents a key pathway to advance agricultural and rural modernization (Bai et al., 2024). As a major agricultural country, China has a substantial rural population, and its agricultural production plays significant roles nationally. Agriculture is not only the foundation of China’s food security, but also an important link to support the development of industry and services (Liu and Li, 2025). Statistical data show that the contribution rates of agriculture and related industries in China’s national economy have remained high for a long period of time; in particular, they play an irreplaceable role in solving rural employment, increasing farmers’ income, and stabilizing social and economic operations (Xu and Yang, 2025). Leveraging digital technology to empower rural development is both a critical imperative for adapting to the digital economy era and an effective approach to tackling urban–rural development imbalances. This process enhances agricultural production efficiency, optimizes resource allocation, and injects new momentum into extending agricultural value chains (Jiang, 2024). Agricultural economic development is an important part of rural revitalization and a core task to guarantee national food security and enhance the international competitiveness of agriculture (Xu Q. et al., 2024). Agricultural economic development manifests not

only in enhanced production output and quality, but also through agricultural value chain upgrading, improved production efficiency, and sustained growth in farm incomes (He et al., 2025). In recent years, China’s agricultural economy has faced many challenges in the process of modernization, such as increased pressure on resources and the environment, accelerated labor migration, and intensified competition in the international market; however, it has also ushered in opportunities brought about by the new technological revolution. Driving high-quality agricultural development through scientific innovation and institutional reform now defines the foundational strategy for agro-economic advancement in the new era (Deng et al., 2024).

To explore the impact of digital rural construction policies on the rural economy and its internal mechanisms, this study utilizes Chinese county-level panel data with double-difference models from 2011 to 2022 to conduct empirical tests. The results of the study show that the digital village policy has strongly promoted the development of the agricultural economy, which fully confirms the key role of this policy in promoting agricultural economic construction and improving the quality of rural development. In addition, this study further conducts an in-depth exploration of the specific paths of digital rural construction policies in promoting the agricultural economy and the variability of policies in different regions. This study provides a basis for optimizing the effectiveness of policy implementations and promoting sustainable development in rural areas around the world.

This study aims to contribute to both academic research and practical applications. First, at the level of academic theory, through in-depth exploration of the intrinsic link between digital village policies and agricultural economic development, this study provides a theoretical framework for understanding how macropolicies drive rural economies and helps to enrich the research on policy drivers in agricultural economic settings. Second, we address the research methodology. This study uses a double-difference model to explore the transmission mechanism of digital rural construction policy on the rural economy, which helps to enrich the study of the digital economy’s effects. Finally, practical applications are needed. The findings of this study provide exemplary significance and reference for rural underdeveloped countries and regions globally, helping to carry out the construction of digital villages and promote the sustainable development of the agricultural economy.

The remainder of this paper is organized as follows: Section 2 systematically determines the root causes of agricultural economic distress in developing countries and analyzes the mechanisms of government policies and digital technologies, explaining the policy system of rural digitalization in China; it also proposes the theoretical hypothesis that rural digitalization promotes agricultural economic development through three major paths: enhancing agricultural productivity, accelerating urbanization, and strengthening the innovation capacity of counties. Section 3 presents the study design, including the sources of county-level panel data in China from 2011 to 2022, definitions of core variables (e.g., agricultural productivity, urbanization rate, etc.), and the basic model setting of the double-difference method. Section 4 analyzes the empirical results reflecting the impacts of digital village policies on the agricultural economy. Section 5 further analyzes the mechanisms and the heterogeneity. Section 6 synthesizes key findings and policy insights.

2 Background and theoretical hypotheses

2.1 Literature review

2.1.1 Agricultural economic development and its dilemmas in developing countries

The agricultural economies of developing countries generally face the twin dilemmas of lagging productivity gains and market inefficiencies. Information asymmetry in agricultural markets of developing countries increases farmers' search costs and transaction costs, leading to price distortions and efficiency losses. Digital technologies can reduce information acquisition costs, break down "information barriers," enable farmers to directly connect with markets, and enhance their bargaining power (Antonelli, 2003). In terms of the allocation of factors of production, insufficient capital inputs and slow diffusion of technology have led to long-term low-level equilibrium in agricultural productivity (Hu L. et al., 2025). Land fragmentation and unclear property rights further exacerbate the inefficiency of resource allocation and form institutional barriers to agricultural modernization (Canwat and Onakuse, 2022). In terms of market mechanisms, information asymmetry and high transaction costs result in the inefficient circulation of agricultural products and weak value-added capacity in the value chain (Nhlengetfwa and Mamba, 2024). This structural dilemma has caused the growth rate of agricultural total-factor productivity (TFP) in developing countries to lag behind that of developed countries by 1.3 percentage points over time (Food and Agriculture Organization of the United Nations, 2023). Consequently, serious constraints have been imposed on agricultural economic development and the growth of farmers' incomes. Deeper constraints arise from the interaction between the institutional environment and external shocks. Poor institutional quality leads to inefficient policy implementation, creating "institutional traps" (Hao and Ki-Seong, 2024). Climate change exacerbates uncertainties in agricultural production and exposes traditional agricultural systems to unprecedented adaptation challenges (Intergovernmental Panel on Climate Change, 2023). The vulnerability of developing countries' agricultural economies is further amplified by the market volatility associated with the reconfiguration of global value chains (WTO, 2023). Together, these factors form a complex system of constraints that demand breakthrough solutions.

2.1.2 The role of government or public policy in agricultural development

The government plays the dual role of a market failure corrector and system provider in the context of agricultural development. Traditional agricultural policies have relied mainly on price support and input subsidies, but such interventions often lead to market distortions and efficiency losses (Chen and Gao, 2025). Recent studies have emphasized that effective agricultural policies require a "market-friendly" framework of interventions to promote market dynamism by improving the institutional environment (Swami and Parthasarathy, 2024). This paradigm shift is reflected in three areas: from direct intervention to institutional provision, from single policies to policy mixes, and from short-term relief to long-term capacity-building (Song B. et al., 2025). Institutional innovation has become the key to overcoming the bottleneck of agricultural transformation. The reform of the property rights system can significantly improve the efficiency of land resource allocation (Zhao et al., 2024). The application of

digital governance tools can reduce the cost of policy implementation (Zheng et al., 2025). The government needs to build a rural industrial governance network leveraging the collaborative effect of multiple subjects, thus achieving precise matching between public policy tools and the rural industrial structure and endowment structure, and thereby achieving the revitalization and development of the agricultural sector (He et al., 2025). This new policy paradigm emphasizes the activation of market mechanisms through institutional innovation, rather than substituting for market functions.

2.1.3 Internet: the role of digital technologies in agricultural development

To move beyond fragmented analyses of discrete technologies or impacts, this study further draws upon the Digital Agriculture Innovation Systems framework (Schnebelin et al., 2021). This theoretical lens conceptualizes transformative change not as the linear adoption of isolated tools, but as the outcome of dynamic interactions within a system comprising knowledge creation, technology application, institutional design, and multi-actor networks. Digital technologies offer breakthrough solutions for agricultural development by changing the ways in which information is delivered and reconfiguring the production function. At the theoretical level, digital technology facilitates agricultural transformation through three mechanisms: reducing information asymmetry (Fakhraddine et al., 2025), optimizing resource allocation (Huang and Quan, 2025), and creating new value growth (Ye, 2025). Together, these mechanisms can effectively overcome the path dependence of traditional agricultural development. The enabling effect of digital technology depends on the suitability of the institutional environment. Research has shown that the introduction of technology alone has difficulty in producing a sustained impact, and positive interactions with local institutional conditions must be achieved (Jiang et al., 2024). Effective digital agricultural development requires the construction of support systems, including infrastructure, human capital, and institutional frameworks (GSMA, 2023). In particular, with respect to the market-based allocation of data elements, there is a need for governance mechanisms that balance efficiency and equity (OECD, 2022). This synergistic technology–institution perspective provides a new theoretical framework for understanding the transformation of digital agriculture. Future research needs to further explore the complex mechanisms at play in the transformation of digital technologies and agriculture, especially the differentiated manifestations at different stages of development and in different institutional environments. Moreover, attention needs to be paid to emerging challenges, such as the digital divide and data sovereignty, in order to build a more inclusive paradigm for digital agriculture development (Food and Agriculture Organization of the United Nations, 2023). An in-depth study of these issues will provide important theoretical guidance and policy insights for the modernization of agriculture in developing countries.

Although existing research has systematically elucidated the structural constraints of agricultural transformation in developing countries (Li et al., 2025), the direction of innovation in policy instruments (Aboagye-Darko and Mkhize, 2025), and the potential of digital technologies (GSMA, 2023), several key limitations remain. First, the research perspective shows "mechanism fragmentation," exploring the individual paths of productivity enhancement, urbanization drive, and innovation empowerment in isolation, thus failing to reveal the synergistic evolution mechanism at the county level. Second, policy analyses are stuck in the dualistic "state–market"

paradigm, thus ignoring the third path of the “active government + effective market” in China, and especially lacks empirical testing of the three-dimensional “system–technology–space” empowerment framework for digital village policies. Third, research on technology diffusion overly relies on macro-statistics or micro-surveys, neglecting the meso-mechanism of counties as the “hub for the conversion of urban and rural elements,” which leads to a “black-box effect” in the evaluation of policy effectiveness (OECD, 2023).

2.2 Policy of digital village development in China

In recent years, the Chinese government has taken the construction of rural digitalization areas as an important part of the digital China strategy, issued a series of policy documents of strategic significance, and gradually built a systematic framework and policy system. China's digital village policy is a key component of the state's strategy to promote rural revitalization, with the aim of empowering the modernization of agriculture and rural areas through digital technology, narrowing the digital divide between urban and rural areas, and promoting common prosperity. In 2024, the Digital Countryside Construction Guide 2.0 was jointly released by the Central Internet Information Office and six other departments. The principles of adapting measures to local conditions and implementing differentiated policies, emphasizing scientific planning and implementation, and preventing blind expansion and waste of resources were proposed. In 2023, the Overall Layout Plan for the Construction of Digital China systematically designed a framework for the construction of digital China at the national level, focusing on the construction of digital infrastructure and data resource systems, and promoting the in-depth integration of digital technology with various fields, such as agriculture, education, and healthcare. In 2022, the Action Plan for the Development of Digital Villages (2022–2025) specified the core tasks of digital rural construction in the 14th Five-Year Plan period, including the upgrading of rural digital infrastructure, the innovative development of smart agriculture, and the enhancement of digital capacity in rural governance. The twentieth report emphasized “accelerating the construction of a strong agricultural country and solidly promoting the revitalization of the countryside,” and clearly pointed out the key role of digital technology in the modernization of agriculture and rural areas. The above policy system profoundly reflects the strategic importance that the state attaches to the construction of rural digitalization areas. In theory, it provides a top-level design for the development of rural digitalization areas and, in practice, it promotes the transformation of the rural economy and the optimization of the social governance model. These policy measures have enhanced the effectiveness of rural governance and improved rural livelihoods by empowering agricultural production; they have injected strong impetus into the modernization of agriculture and rural areas, and also provide important reference for the international community's research and practice in the field of rural digitalization.

2.3 Theoretical analysis and hypotheses

The core of high-quality growth in the agricultural economy lies in improving the efficiency, sustainability, and stability of growth; optimizing the agricultural structure; and improving the welfare level

of farmers (Njuguna et al., 2025). In addition, rural digitalization—as a core driving force that promotes the high-quality development of the agricultural economy—reconstructs the development paradigm of traditional agriculture through the systematic integration of modern information technology (Shadkam and Irannezhad, 2025). This transformation process has the fundamental objectives of enhancing total-factor productivity in agriculture and focusing on identifying the key bottlenecks constraining the development of the agricultural economy. Its core values lie in optimizing resource allocation efficiency, innovating industrial forms, and upgrading development concepts through digital means, forming a path of agricultural modernization with Chinese characteristics (Lin et al., 2025).

At the factor allocation level, digital technologies profoundly change the intrinsic structure of the agricultural production function (Dibbern et al., 2024). By enhancing land-use efficiency through precise spatial information management, relying on mobile internet technology to break through the constraints of human capital development, and optimizing the flow of capital factors with the help of financial science and technology, these changes have significantly improved the ways in which factors can be combined in traditional agricultural production (Yang et al., 2024). This digital reconstruction at the factor level provides new basic conditions for the agricultural economy to overcome resource and environmental constraints and achieve intensive development.

From the perspective of business entities, digital transformation shows distinct characteristics of classified advancement. Small farmers effectively connect to the large market through e-commerce platforms, and new business subjects use intelligent equipment to improve production efficiency. Agricultural enterprises can build a digital supply chain management system, and different subjects—on the basis of their own characteristics—can explore different development paths (Chen and Li, 2025). This multilevel and diversified pattern of transformation has created a gradient of quality, efficiency, and power changes in the agricultural economy.

With respect to functional realization, rural digitalization promotes the formation of a new paradigm of development that synergistically enhances economic, ecological, and social benefits (Li and Wang, 2025). In the economic dimension, it has promoted sustained improvements in industrial efficiency. In the ecological dimension, a new model of green development has been constructed. In the social dimension, it has provided innovation to the rural governance system. These systemic changes have enabled agricultural economic development to overcome the limitations of a single production function. Through the deep integration of digital technology with agriculture and rural areas, a more efficient, inclusive, and sustainable modern agricultural economic system is being built.

As a core engine for the high-quality development of the agricultural economy, rural digitalization systematically promotes the modernization of traditional agriculture through the three-dimensional drive of factor reconstruction, empowerment, and functional upgrading. This development path with Chinese characteristics has cracked the double dilemma of resource and environmental constraints and market inefficiency. Furthermore, the deep integration of digital technology and institutional innovation has contributed practical solutions that can be drawn on for the modernization of global agriculture. Future research should further explore the differentiated performance of the digital empowerment effect under different regional conditions, in order to provide a new empirical basis for constructing more inclusive and adaptive

theoretical frameworks for agricultural digital transformation. Hence, the following hypothesis is made in this study:

Hypothesis 1: Rural digitalization effectively enhances the agricultural economy.

Rural digitalization provides new ideas and methods for high-quality agricultural development. This has become a driving force for enhancing agricultural productivity (Hu et al., 2024). Increasing agricultural productivity is another important mechanism for modernizing agriculture through rural digitalization (Cao and Wang, 2024). The application of digital technology not only improves the productivity of land, labor, and capital, but also significantly reduces the waste of resources in agricultural production (Jiang et al., 2024).

First, digital solutions optimize agricultural resource management. The adoption of remote sensing, drone systems, and IoT devices enables real-time monitoring of field conditions and crop dynamics (Wang and Li, 2024). For example, smart agricultural systems use sensors and big data analysis to guide farmland irrigation, fertilization, and pest control accurately, thereby dramatically increasing the output efficiency per unit of land. This technology-enabled refinement not only reduces production costs, but also reduces the negative impact on the environment (Wen et al., 2024b).

Second, rural digitalization improves the productive capacity of the rural labor force through knowledge sharing and technology dissemination. Online education and distance training platforms enable farmers to access the latest agricultural technologies and market information (Kitole et al., 2024). For example, the Ministry of Agriculture in Rural China, in collaboration with a number of science and technology enterprises, has launched “Farmer Training on the Cloud,” which helps farmers to master e-commerce operation skills and intelligent farming techniques. This knowledge empowerment not only improves the overall ability of farmers, but also provides intellectual support to increase agricultural productivity.

Finally, digital technologies allow for innovation in agricultural production methods. For example, the “order agriculture” model achieves accurate matching of the supply and demand of agricultural products through digital platforms, avoiding farmers’ blind cultivation and the problem of mismatch between supply and demand in the market (Wen et al., 2024a). In addition, digital platforms have promoted the development of an agricultural sharing economy; for example, shared agricultural machinery and land hosting services have further improved the efficiency and scale of agricultural production.

Future rural digitalization necessitates tripartite strategic prioritization: (1) Accelerated deployment of broadband infrastructure to resolve spatial connectivity asymmetries; (2) Scaled implementation of certified digital literacy programs targeting agricultural labor forces; (3) Ecosystem expansion for applied technologies, particularly parametric agricultural insurance and digital microfinance solutions, to catalyze systemic productivity transformation. In summary, the following hypothesis is made:

Hypothesis 2: Rural digitalization promotes agricultural economic development by increasing agricultural productivity.

With its core qualities of innovation-driven system integration, in-depth penetration, and open sharing, rural digitalization is highly compatible with the development strategy of new-type urbanization,

and it has injected new development momentum into the urbanization process. The construction of the digital countryside promotes the synergistic development of industries and the construction of a unified national market, improves the infrastructure and public service system, strengthens the digital transformation of grassroots governance, and optimizes the allocation of the flow of production factors by promoting the synergistic development of industries. This can effectively facilitate the implementation of the rural revitalization strategy, promote the common prosperity of society, and accelerate the modernization and development process with Chinese characteristics (Chen et al., 2025).

Through the synergistic mechanism of industrial empowerment, governance upgrading, and factor optimization, rural digitalization accelerates the process of new urbanization and, thus, strongly promotes the development of the agricultural economy (Hu M. et al., 2025). At the industrial level, the digital economy is centered on the whole industrial chain system of “digital agriculture, intelligent processing, and e-commerce logistics,” and the total-factor productivity of agriculture in pilot counties has significantly improved (Lu et al., 2024). At the same time, it has spawned artificial intelligence, smart agriculture, and other convergent industries, promoting the continued expansion of the scale of the digital economy in these counties. Rural digitalization effectively reduces the degree of resource mismatch through the cross-domain flow of data elements, alleviating the contradiction between resource constraints in SMEs and the hollowing out of rural areas under the siphoning effect of large cities. Moreover, the innovation-driven urbanization development paradigm injects technology and market momentum into agriculture (Radoine and Nahiduzzaman, 2025). At the governance level, relying on the “one network,” “city brain,” and other technological structure concepts, the depth of the administrative process is re-engineered to promote the governance model for intelligent decision making, significantly improving the efficiency and quality of public service provision, while also reducing running costs. Moreover, algorithm optimization strengthens urban management refinement and emergency response capabilities and promotes the balanced allocation of public resources. The fruits of urbanization more equitably benefit urban and rural residents, reducing systemic transaction costs and increasing development vitality for agricultural business entities (Zhao et al., 2023). At the factor level, the construction of rural digitalization areas is characterized by information transparency to break down traditional barriers to factor allocation. Accurately matching human resources through the urban and rural talent information platform and cross-platform data sharing can enhance the effectiveness of docking capital and land elements. This not only forms a virtuous cycle of synergy between supply and demand, but also introduces modern production factors for agriculture through the factor integration function of urbanization and promotes the transformation of agriculture from single production to the integration of “production + service” (Jiang et al., 2022). These three mechanisms are nested within one another. Industrial innovation injects core kinetic energy into urbanization, governance optimization guarantees the stability of development, and factor circulation strengthens the foundation of development. Eventually, through the acceleration of the urbanization process (Wang et al., 2021) and the diffusion effect of digital technology, the synergistic effect of governance and the aggregation effect of factors will be transformed into a new kinetic energy source for the digitization of the agricultural economy and the upgrading of intensification, achieving the sustainable development pattern of

“bringing the countryside to the city and promoting agriculture with numbers.”

Hypothesis 3: Rural digitalization promotes the agricultural economy by accelerating urbanization processes.

The construction of rural digitalization areas can significantly improve the level of scientific and technological innovation and enhance the entrepreneurial activity of the county, thereby promoting the development of the agricultural economy (Tang et al., 2025). By building a county innovation ecosystem, rural digitalization systematically promotes the transformation and upgrading of the agricultural economy, and its mechanism of action is characterized by a threefold innovation-driven pathway. First, policy-guided digital infrastructure construction and smart technology application support create an environment of institutional security for agricultural technology iteration (Wang et al., 2025). Second, the Internet of Things and big data platforms are deeply embedded in the agricultural production system, significantly optimizing the technology research and development process and overcoming the bottleneck of traditional production efficiency. The digital circulation system promotes the market-oriented transformation of agricultural scientific and technological achievements, forming a benign interaction between technology application and economic benefits (Dimitrijević, 2023). This innovation-driven model effectively improves the allocation efficiency of agricultural production factors, promotes value upgrading in the industrial chain, and accelerates the transformation of traditional agriculture into intelligent agriculture. Through the construction of cross-regional technical collaboration networks, rural digitalization promotes the spatial overflow of knowledge elements, forms a regional synergistic innovation pattern, and injects sustained kinetic energy into the high-quality development of the agricultural economy.

Hypothesis 4: Rural digitalization promotes agricultural economic development by increasing county innovation capacity.

The theoretical framework is depicted in Figure 1.

3 Data sources and research methods

3.1 Model specification

To investigate the impact of rural digitalization on agricultural economic development, a study was carried out based on the research hypotheses proposed above. In this study, the implementation of China’s digital village pilot policy is viewed as a quasi-natural experiment, and the following baseline model is set up via a difference-in-differences (DID) model:

$$Agric_{Ecoit} = \alpha_1 + \beta_1 DID_{DVit} + \gamma Controls_{it} + \mu_i + \eta_t + \varepsilon_{it} \quad (1)$$

where $Agric_{Ecoit}$ is an explanatory variable that represents the level of economic development of rural county i in China during year t . The difference-in-differences term DID_{DVit} indicates whether rural county i is a digital rural construction pilot area in year t . The coefficient β_1 is the core coefficient of interest in this paper study. $Controls_{it}$ is the control variable, α_1 is a constant term, η_t is a year fixed effect, and μ_i is a county fixed effect, and ε_{it} is a randomized disturbance term.

3.2 Definitions and descriptions of the variables

- (1) Explanatory variables: Agricultural economic development ($Agric_{Ecoit}$) is measured by the natural logarithm of county-level agricultural value added. This indicator captures the sector’s net economic output after deducting intermediate inputs, providing a direct and robust measure of its scale, productive efficiency, and contribution to local economic growth. Compared to gross output value, it more accurately reflects the qualitative dimension of development by focusing on value creation, thereby aligning with the study’s core focus on high-quality agricultural development driven by digital transformation.
- (2) Core explanatory variables: The core explanatory variable is the digital village pilot policy, constructed as a

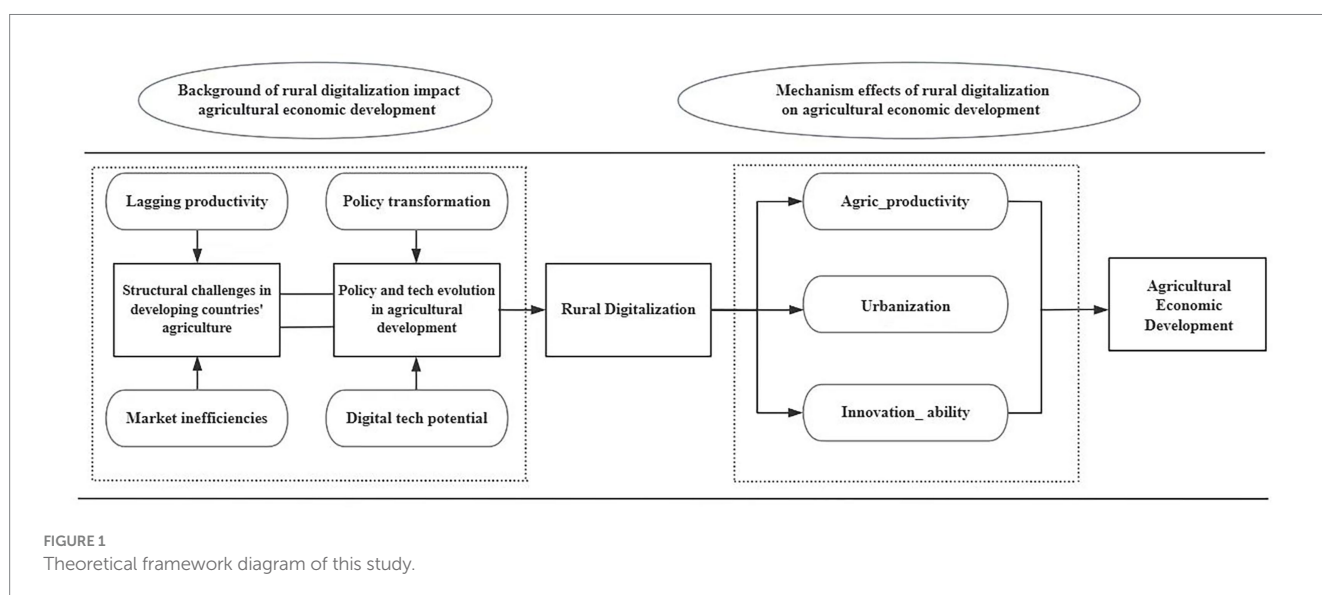


FIGURE 1 Theoretical framework diagram of this study.

Difference-in-Differences (DID) estimator (DID_DV_{it}). It is the interaction term between a county's treatment status and the post-policy period. Specifically, a county is assigned to the treatment group if it is ever designated as a national digital village pilot. The variable DID_DV_{it} takes the value of 1 for all years t in which county i is in the post-pilot period, and 0 otherwise. This specification captures the average causal effect of the policy by comparing the outcome change in pilot counties before and after the reform relative to the change in non-pilot counties.

- (3) Control variables: To explore the net effect of rural digitalization on agricultural economic development, a total of seven control variables were selected in this study. First, the level of regional economic development ($\ln GDP$) is one of the most important factors affecting agricultural economic development, which is measured in this study by taking the logarithm of the gross national economic product of the county. Second, the level of regional financial development ($Finance_Development$): A good financial environment can promote the smooth operation of the agricultural economy. This study uses the ratio of financial institutions at the end of the loan balance to the county's gross regional product to measure the level of regional financial development. Third, the level of regional education (EdU) affects the quality of human resources which, in turn, affects agricultural economic development. This study uses the ratio of the number of students enrolled in general secondary schools to the total population of the county to measure the level of regional education. Fourth, we chose to measure the ratio of the number of employed people to the total number of people in the village ($People$). Fifth, the degree of regional digitization ($Digitization$) can significantly affect the level of agricultural economic development. This study takes the logarithm of county information technology service employment to measure this measure. Sixth, agricultural employment ($Agric_employment$): This study measures the ratio of total agricultural employment to total employment in the county area. Seventh, the level of medical care ($Medicalcare$): This study measures the level of medical care using the

logarithmic value of the number of beds in county hospitals and health centers.

- (4) Mechanism variables: $Agric_productivity$, $Urbanization$, and $Innovation_ability$ were selected as mechanism variables in this study, where agricultural productivity is measured as the ratio of total agricultural, forestry, livestock, and fisheries production to the total crop production area. The urbanization rate is measured as the ratio of the number of people living in cities and towns to the total population of the country. Innovative capacity is measured by taking the logarithm of the number of utility model patent applications filed by the county in the year. The definitions and measurement methods of the variables are detailed in [Table 1](#).

3.3 Data sources

This study explores the impact of rural digitalization on agricultural economic development via 2011–2022 Chinese county panel data from the 2011–2022 China County Statistical Yearbook. The descriptive statistics of the variables are shown in [Table 2](#). In this study, 23,868 annual observations from 1989 counties in rural China were finally obtained via routine cleaning of the data and elimination of areas with many missing data.

4 Empirical results and analysis

4.1 Benchmark analysis

The Stata17 software was used to analyze the data in this study based on [Equation 1](#). [Table 3](#) presents the results of the benchmark regression of rural digitalization on agricultural economic development via a progressive regression strategy, where columns (1), (3), and (5) are the cases where control variables are not included. The coefficients of the core explanatory variables are 0.6244, 0.4078, and 0.2519, respectively, after adding year and county fixed effects step by step. Column

TABLE 1 Explanations of variables.

Variable type	Variable name	Unit	Definition/measurement
Dependent variable	$Agric_Eco$	CNY	Natural logarithm of county-level agricultural value added
Core explanatory variable	DID_DV	Dummy variable (0/1)	Interaction term: 1 if county is a digital village pilot in year t , otherwise 0
Control variables	$\ln GDP$	CNY	Natural logarithm of county GDP
	$Finance_Development$	%	Loan balance of financial institutions/county GDP
	EdU	%	Number of students in general secondary schools/total county population
	$People$	%	Employed population/total village population
	$Digitization$	person	Natural logarithm of employment in information technology services
	$Agric_employment$	%	Agricultural employment/total employment
	$Medicalcare$	Number	Natural logarithm of number of beds in hospitals and health centers
Mechanism variables	$Agric_productivity$	10 k CNY/hectare	Total output of agriculture, forestry, animal husbandry, fishery/total crop area
	$Urbanization$	%	Urban population/total county population
	$Innovation_ability$	Number	Natural logarithm of utility model patent applications

(1) is significant at the 1% level, and columns (3) and (5) are significant at the 5% level. Columns (2), (4), and (6) include control variables, for which year and county fixed effects are added stepwise, and the results are all significant at the 1% level. The results in columns (2) and (6) of Table 3 indicate that the coefficient of the core explanatory variable is 0.2547 when the year and county fixed effects are combined and all control variables are included. The results of the benchmark regression show that rural digitalization and construction can significantly contribute to the development of the agricultural economy. The core explanatory variables under different forms of model setting are all significant, and the coefficients are all positive. The results of the positive impact of rural digitalization and construction on agricultural economic development are relatively robust, and Hypothesis 1 is preliminarily verified.

4.2 Parallel trend test

Parallel trends are necessary for double-difference estimation. This implies that, prior to the implementation of the digital village policy, these two distinct groups of counties did not differ significantly in their level of agricultural economic development; i.e., the common trend hypothesis was met. For this purpose, the following model was developed.

$$Agric_{Ecoit} = \alpha_1 + \sum_{k=-6}^{-1} \beta_k before_{i,t+k} + \sum_{k=1}^2 \beta_k after_{i,t+k} + Controls_{it} \gamma + \mu_i + \eta_t + \varepsilon_{it} \tag{2}$$

The core explanatory variables are *before_{i,t}* and *after_{i,t}*, which are dummy variables indicating the year of implementation of the

TABLE 2 Descriptive characteristics of related variables.

Variable	Observation	SD	Median	Min	Max
<i>Agric_Eco</i>	23,868	1.222	1.406	0.008	13.153
<i>DID_DV</i>	23,868	0.112	0.000	0.000	1.000
<i>lnGDP</i>	23,868	0.965	14.361	10.544	18.345
<i>Fin_dev</i>	23,868	0.864	0.622	0.000	52.476
<i>EdU</i>	23,868	0.042	0.046	0.000	1.617
<i>People</i>	23,868	0.673	0.789	0.008	21.858
<i>Digitization</i>	23,868	0.906	11.146	5.142	16.524
<i>Agric_employment</i>	23,868	0.833	11.536	6.410	14.261
<i>Medicalcare</i>	23,868	0.816	7.531	0.000	10.063
<i>Agric_productivity</i>	20,142	0.117	0.159	0.000	1.273
<i>Urbanization</i>	20,879	0.197	0.217	0.000	0.998
<i>Innovation_ability</i>	23,868	0.030	0.004	0.000	2.039

TABLE 3 Results of benchmark DID regression.

Variables	<i>Agric_Eco</i>					
	(1)	(2)	(3)	(4)	(5)	(6)
<i>DID_DV</i>	0.6244*** (8.850)	0.5931*** (11.172)	0.4078** (2.016)	0.5091*** (3.036)	0.2519** (2.551)	0.2547*** (2.681)
<i>lnGDP</i>		0.3471*** (37.438)		0.3458*** (11.875)		0.4505*** (12.579)
<i>Fin_dev</i>		-0.0294*** (-4.169)		-0.0399** (-2.111)		0.0092 (0.843)
<i>EdU</i>		-4.5828*** (-19.357)		-4.6681*** (-5.653)		-0.8118* (-1.886)
<i>People</i>		0.3107*** (20.893)		0.3129*** (6.267)		0.1513*** (3.389)
<i>Digitization</i>		0.0146* (1.934)		-0.0004 (-0.017)		0.0266* (1.704)
<i>Agric_employment</i>		0.5366*** (61.974)		0.5499*** (16.857)		-0.1127 (-1.590)
<i>Medicalcare</i>		0.2516*** (20.751)		0.2332*** (5.204)		0.1134*** (3.856)
_cons	1.6529*** (207.919)	-11.5233*** (-92.688)	1.6556*** (64.433)	-11.3413*** (-23.923)	1.6576*** (1322.022)	-4.7643*** (-5.001)
County FE	No	No	No	No	Yes	Yes
Year FE	No	No	Yes	Yes	Yes	Yes
R-Squared	0.003	0.438	0.023	0.441	0.914	0.920
Observations	23,868	23,868	23,868	23,868	23,868	23,868

Robust t_statistics in parentheses ***p < 0.01, **p < 0.05, *p < 0.1.

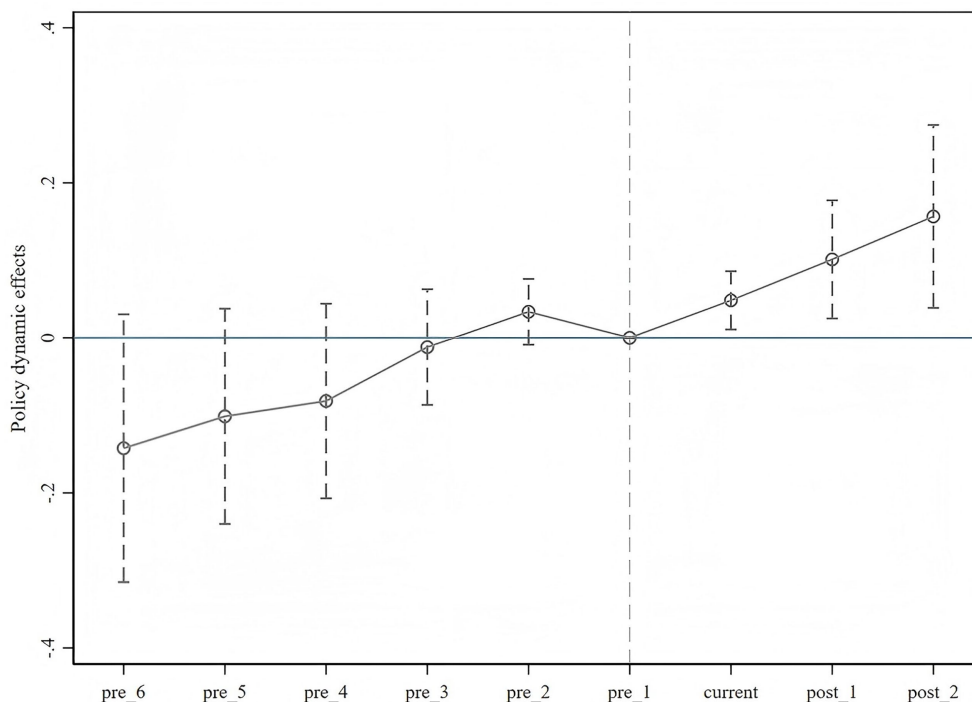


FIGURE 2 Results of the parallel trend test.

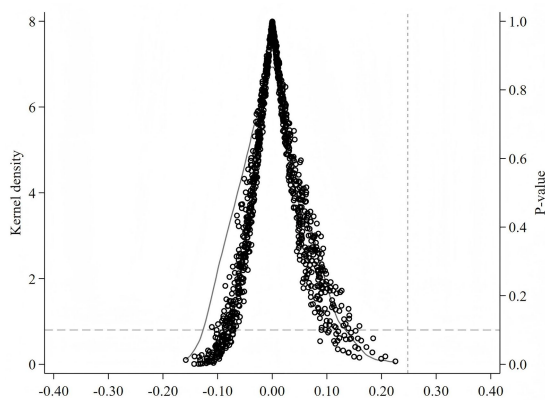


FIGURE 3 Results of placebo test.

digital village policy; $before_{i,t}$ takes a value of 1 if the pilot area is in year t before the policy is implemented, and 0 otherwise; $after_{i,t}$ is the same. The policy was not released until 2020, and there was a lag in data collection. Parallel trend tests were conducted using Equation 2, choosing 6 years before and 2 years after the policy implementation as forward-looking and lagged indicators, respectively. The results are shown in Figure 2, where the confidence intervals of the estimated coefficients for the pre-pilot digital village policy intersect the horizontal axis, with a smooth trend. This suggests that there was no significant difference in agricultural economic development between these two types of

counties prior to digital countryside rural policy intervention. However, after the implementation of the policy, the level of agricultural economic development in the pilot counties was significantly greater than that in the non-pilot counties. This further validates the hypothesis that the digital village policy can have a positive effect on agricultural economic development.

4.3 County placebo test

To verify that unobservable omitted variables did not affect the baseline regression results, and drawing on previous methods for avoiding shocks from un-observable omitted variables, this study implemented a placebo test by randomly replacing the sample counties in the treatment group. Of the 1989 counties in the study sample, 100 counties were randomly selected and set as the experimental group, while the remaining areas were set as the control group. The 1,000 regressions assumed that the year of implementation of the digital village policy was 2020. As shown in Figure 3, the coefficients generated by the spurious policy shocks follow a normal distribution of approximately 0, whereas the p values are mostly far from 0, and the placebo test is passed. This further proves the robustness of the model.

4.4 PSM-DID test

To avoid bias in the regression results due to sample selection bias, this study adopted the double-difference method of propensity score matching (PSM) for robustness testing. Three methods—1:1

nearest-neighbor matching, kernel matching, and caliper matching—were also used for testing. The impact of the digital village policy on agricultural economic development was then re-estimated, and the specific results are shown in Table 4. As shown in columns (2), (4), and (6) of the table, the DID_DV coefficients are significantly positive for all three methods, which is consistent with the hypothetical case of this study and the results of the benchmark regression. This further confirms the reliability of the findings of this study.

4.5 Exclusion of other intrusive policy tests

This text argues that there may be confounding factors from other policies in the course of the study that prevent the policy effects from being easily identifiable. First, the comprehensive demonstration policy for e-commerce in rural areas mainly promotes agricultural economic development by improving the rural e-commerce infrastructure and expanding financing and agricultural product sales channels (Peng et al., 2021). Therefore, this study constructed a dummy variable based on whether the county in which the sample is located implements the comprehensive demonstration policy of e-commerce in rural areas. If the county where the sample is located is a comprehensive demonstration county for e-commerce in rural areas, the value is 1; otherwise, it is 0. Second, the new urbanization pilot promotes the flow of resource factors through urban–rural integration, industrial upgrading, and infrastructure

improvement, driving increases in rural employment and entrepreneurship and farmer income (Ma and Shi, 2023). If the county where the sample is located is in the new urbanization pilot area, it is assigned a value of 1; otherwise, it is 0. Third, the pilot reform of the rural collective property rights system can create a good economic environment for county entrepreneurship by promoting agglomeration, driving employment, optimizing the structure, and other channels. This, in turn, has a positive effect on rural entrepreneurship (Xu G. et al., 2024). Similarly, if the sample is located in the area of the rural collective property rights system, reform pilot counties are assigned a value of 1; otherwise, they are assigned a value of 0. On this basis, this study incorporates the three variables of e-commerce into a rural comprehensive demonstration policy, a new urbanization pilot policy, and a rural collective property rights system reform pilot in the model. As can be seen from the results in column (6) of Table 5, the regression coefficients of the model for the digital village policy on agricultural economic development are all significantly positive at the 1% level after the introduction of the dummy variables for the above three policies. This is consistent with the results of the benchmark regression.

4.6 Other robustness tests

This study also used two other methods for robustness testing: First, some samples were excluded. The digitization and economic levels of the

TABLE 4 Results of PSM-DID.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	1:1 Nearest neighbor match		Kernel density match		Caliper match	
DID_DV	0.2203*** (2.763)	0.1716** (2.305)	0.2523*** (9.836)	0.2514*** (10.187)	0.2523** (2.553)	0.2514*** (10.187)
_cons	1.2651*** (26.262)	−14.8882*** (−9.055)	1.3390*** (157.024)	−5.0921*** (−12.911)	1.3390*** (130.922)	−5.0921*** (−5.129)
Controls	No	Yes	No	Yes	No	Yes
R-Squared	0.240	0.348	0.205	0.265	0.205	0.265
Observations	2,360	2,360	23,390	23,405	23,390	23,405

Robust t_statistics in parentheses ***p < 0.01, **p < 0.05, *p < 0.1.

TABLE 5 Results of the robustness test excluding other policy effects.

Variables	Agric_Eco					
	(1)	(2)	(3)	(4)	(5)	(6)
DID_DV	0.2486** (2.519)	0.2491*** (2.632)	0.2459** (2.492)	0.2476*** (9.887)	0.2457** (2.492)	0.2472*** (2.614)
DID_EC	0.0447** (2.104)	−0.0014 (−0.070)	0.0443** (2.086)	−0.0015 (−0.158)	0.0438** (2.056)	−0.0024 (−0.120)
DID_UB			0.0572*** (2.848)	0.0363*** (3.281)	0.0561*** (2.671)	0.0338* (1.729)
DID_CP					0.0047 (0.233)	0.0102 (0.528)
_cons	1.6331*** (316.965)	−5.1369*** (−5.102)	1.6257*** (283.460)	−5.1582*** (−12.193)	1.6250*** (251.949)	−5.1613*** (−5.143)
Controls	No	Yes	No	Yes	No	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.913	0.920	0.914	0.920	0.914	0.920
Observations	22,308	22,308	22,308	22,308	22,308	22,308

Robust t_statistics in parentheses ***p < 0.01, **p < 0.05, *p < 0.1.

four municipalities of Beijing, Shanghai, Tianjin, and Chongqing differ significantly from those of other counties, and their levels are in the leading position. Therefore, to ensure the robustness of the findings, this study excludes data from these municipalities; it also re-examines the impact of digital village policies on agricultural economic development. According to the results in column (3) of Table 6, the regression coefficients of digital village policies on the rural economy after re-moving the sample of municipalities are still significantly positive at the 5% level. This further enhances the credibility and stability of this study. Second, the explanatory variables were replaced. In this study, on the basis of the original foundation and referring to the literature, the gross agricultural output value is used to measure agricultural economic development (Gollin, 2010), which was included as a new explanatory variable in the regression model. The results in column (6) of Table 6 show that the regression coefficient of the digital village policy on agricultural economic development remains significantly positive at the 5% level. This result is consistent with the previous benchmark regression results. Thus, the robustness of the regression results is again confirmed.

5 Further discussion

5.1 Discussion on the mechanism

The theoretical derivation in the previous section demonstrated that the agricultural productivity, degree of urbanization, and

innovation ability are important factors affecting the level of agricultural economic development in a county. The previous section demonstrated, in several ways, that digital village policies can significantly boost the agricultural economy; however, there is a need to further test whether the implementation of digital village policies can further boost the agricultural economy by increasing agricultural productivity, accelerating urbanization, and improving innovation capacity. To address the possible estimation bias of the mediated effects models widely used in the literature (Dell, 2010), the following model was constructed.

$$Mechanism_{it} = \delta_0 + \delta_1 DID_{DVit} + \delta_2 Controls_{it} + \mu_i + \eta_t + \varepsilon_{it} \quad (3)$$

where $Mechanism_{it}$ are present the mechanism variables, namely, agricultural productivity, the urbanization level, and innovation ability, and the rest other parameters are consistent with the baseline regression model. Specifically, this study paper measures agricultural productivity as the ratio of total agricultural, forestry, livestock, and fisheries production to the total crop production area. The urbanization rate is measured as the ratio of the number of people in towns to the total population of the county. Innovation capacity is measured by taking the logarithm of the number of utility model patent applications filed in the county during the year. Following Equation 3, the impact of the digital village policy on the agricultural economy is presented in Table 7 through the regression results. As seen from the perspective of

TABLE 6 Results of the robustness test.

Variables	Agric_Eco					
	Delete samples			Replace variable		
	(1)	(2)	(3)	(4)	(5)	(6)
DID_DV	0.5463*** (9.665)	0.2795*** (2.840)	0.2562** (2.534)	0.0232*** (4.306)	0.0237*** (6.420)	0.0075** (2.142)
_cons	-11.3385*** (-90.333)	-5.3678*** (-5.998)	-4.1852*** (-4.392)	0.7757*** (61.926)	0.9787*** (11.528)	1.4111*** (13.022)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
County FE	No	Yes	Yes	No	Yes	Yes
Year FE	Yes	No	Yes	Yes	No	Yes
R-Squared	0.443	0.920	0.921	0.405	0.922	0.929
Observations	23,124	23,124	23,124	23,868	23,868	23,868

Robust t_statistics in parentheses ***p < 0.01, **p < 0.05, *p < 0.1.

TABLE 7 Regression results of the mechanism analysis.

Variables	(1)	(2)	(3)	(4)	(5)	(6)
	Agric_productivity		Urbanization		Innovation_ability	
DID_DV	0.0057** (2.301)	0.0072* (1.830)	0.0819*** (21.685)	0.0839*** (5.553)	0.0016* (1.766)	0.0016* (1.693)
_cons	0.1741*** (687.805)	1.3940*** (14.377)	0.2603*** (695.824)	-1.1528*** (-8.323)	0.0096*** (809.737)	0.0450* (1.825)
Controls	No	Yes	No	Yes	No	Yes
County FE	Yes	Yes	Yes	Yes	Yes	Yes
Year FE	Yes	Yes	Yes	Yes	Yes	Yes
R-Squared	0.916	0.941	0.933	0.938	0.451	0.451
Observations	20,121	20,121	20,876	20,876	23,868	23,868

Robust t_statistics in parentheses ***p < 0.01, **p < 0.05, *p < 0.1.

agricultural productivity, columns (2) show that DID_DV is significant at the 10% level. This indicates that the digital village policy can significantly increase agricultural productivity. From the analysis of the urbanization rate, the results in columns (3) and (4) also show that the estimated coefficient of DID_DV is significantly positive at the 1% level. This implies that the digital village policy has the same significant effect on the urbanization rate. From the innovation ability perspective, the results in columns (5) and (6) continue to indicate that the estimated coefficients of DID_DV are significantly positive at 10% levels, respectively. Thus, Hypotheses 2, 3, and 4 are tested and confirmed.

Our empirical findings on the three transmission channels resonate with, yet contextually extend, the existing body of knowledge. The identified positive mediating role of urbanization empirically validates and extends the theoretical linkage proposed by Jiang et al. (2022), who highlighted the synergistic potential between digital agriculture and urban-rural integration. Our results from Chinese counties demonstrate that the digital village policy does not merely correlate with, but actively accelerates urbanization through structured factor optimization and governance digitization. Regarding agricultural productivity, our conclusion aligns with evidence from other developing contexts, such as the digital transformation observed in Tanzanian agriculture Kitole et al. (2024). However, a key distinction emerges: within China's integrated "digital infrastructure-platform-governance" policy framework, productivity gains are systematically orchestrated alongside institutional innovations, rather than arising from isolated technological adoption. Finally, the significant role of enhanced innovation capacity underscores a distinctive feature of China's model. This suggests that top-down, coordinated policy pilots can effectively stimulate local innovation ecosystems—a nuance that adds a governance dimension to the literature often focused on market-driven or spontaneous technology diffusion.

5.2 Discussion on the heterogeneity

To test the regional heterogeneity of the effects of rural digitalization areas on agricultural economic development, the sample was divided into three regions (east, central, and west) for fixed-effects regression. The results show that the positive effect of rural digitalization on the agricultural economy is significant in the west, while it was not significant in the east and central regions. As shown in Table 8, the coefficient of the core explanatory variable for the western region was 0.3469, and all of the coefficients were significant at the 5% level. In contrast, neither the eastern nor the central regions passed the test of significance. This regional heterogeneity may stem from two sources: first, the western region relies on digital technology to overcome traditional production factor constraints. The agricultural industry chain has been upgraded through the application of e-commerce to help farmers, the implementation of intelligent irrigation, and other scenarios. Second, the better foundation of agricultural digitization in East China and Central China has entered a phase of diminishing marginal benefits. As such, growth in these areas needs to be driven by technological integration and innovation rather than scale expansion.

The pronounced regional heterogeneity—where western China exhibits the strongest positive effects—provides a critical spatial perspective to the literature on the digital economy's uneven impacts. This finding directly engages with the concerns raised by Hu et al. (2024) regarding the spatially divergent consequences of digital economic development. Contrary to scenarios where market forces alone might exacerbate regional disparities, our counter-intuitive result—that the largest policy dividends accrued to the less-developed west—suggests that well-structured national policies can harness digitalization as a "great equalizer" for lagging regions. It indicates that targeted digital infrastructure and services can help overcome traditional factor constraints in less-developed areas. Therefore, our

TABLE 8 Regression results of heterogeneity analysis.

Variables	East	Central	West
	(1)	(2)	(3)
	<i>Agric_Eco</i>		
<i>DID_DV</i>	0.2914 (1.552)	0.1034 (0.978)	0.3469** (2.578)
<i>lnGDP</i>	0.5959*** (9.265)	0.1431** (2.194)	0.3517*** (6.837)
<i>Fin_dev</i>	0.0164 (0.548)	0.0496* (1.656)	0.0045 (0.375)
<i>EdU</i>	-1.3069 (-1.102)	-0.7235* (-1.723)	2.4921*** (2.614)
<i>People</i>	0.2903** (2.305)	0.0720* (1.654)	-0.0394 (-0.496)
<i>Digitization</i>	0.0408 (1.348)	-0.0347 (-1.381)	0.0579** (2.455)
<i>Agric_employment</i>	-0.2546** (-1.991)	-0.0116 (-0.148)	-0.0268 (-0.185)
<i>Medicalcare</i>	0.0728* (1.738)	0.0935* (1.914)	0.2251*** (3.654)
<i>_cons</i>	-5.1630*** (-3.089)	-0.6951 (-0.512)	-5.6017*** (-2.935)
County FE	Yes	Yes	Yes
Year FE	Yes	Yes	Yes
R-Squared	0.921	0.922	0.913
Observations	9,480	7,308	7,080

Robust t_statistics in parentheses *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

analysis highlights the pivotal, and often underemphasized, role of proactive and spatially-sensitive governance in steering digital transformation toward regional convergence, offering a crucial insight for developing countries grappling with significant internal spatial inequalities.

6 Conclusions and highlights

Digital technology holds enormous potential for the modernization of agriculture in rural areas, especially in developing countries. In particular, digital technology can be utilized to address the problems of backward agricultural productivity and insufficient marketization of agricultural products, consequently yielding significant dividends (Wen et al., 2024a). On the basis of the practice of rural digitalization in China, this study examined the impacts of rural digitalization on agricultural economic development. Panel data from various counties and districts were utilized to determine the changing patterns of agricultural economic development, while the DID design was employed to reveal causal relationships. Some of the following conclusions were drawn and verified:

The results show that rural digitalization significantly contributes to the development of the agricultural economy. This finding was validated through different model settings and robustness tests. The key role of digital technology in driving the process of agricultural modernization was confirmed. In addition, the economic benefits of rural digitalization are characterized by a gradient distribution. This is evidenced by the fact that the western region has benefited to a significantly greater extent than the central and eastern regions. This finding provides an important basis for the formulation of differentiated regional development policies.

With respect to the mechanisms of action, this study found that rural digitalization promotes the development of the agricultural economy through three main paths: first, the deep integration of digital technology throughout the entire agricultural production chain should be promoted. The allocation of production factors should be optimized, promoting the transformation of production decisions from experience-driven to data-driven. This, in turn, will accelerate the change in traditional agricultural production methods, foster new forms of agriculture, and ultimately enhance agricultural productivity. Second, relying on digital infrastructure and the “digital agriculture + county e-commerce” model of synergistic linkages, a pattern of two-way flow of factors between urban and rural areas should be developed, attracting local employment for the labor force. The synergistic development of small- and medium-sized towns and rural industries should be promoted, thereby accelerating the urbanization process. A positive interaction involves bringing the countryside to the city, promoting the city within the countryside, and injecting external kinetic energy into the expansion of the scale of the agricultural economy. Third, the threshold of technology diffusion and the cost of innovation application should be lowered, thus accelerating the cross-regional diffusion of new technologies. The market trust mechanism should be strengthened, easing the financial constraints on innovation investment. Then, the innovation capacity of counties can be activated. The transformation of agriculture from traditional to innovation-driven production should be promoted, and internal

energy should be provided for optimization of the structure of the agricultural industry.

These findings are highly important for the rural areas of less developed countries. This study therefore offers the following recommendations: first, investment in rural digitalization should be increased, and the effectiveness of rural digitalization should be enhanced. Given the significant contribution of the digital village policy to the economic development of the county, the continuity and stability of the policy should be maintained, with continuous promotion through financial subsidies, credit preferences, technical assistance, and other multifaceted initiatives. In the process of policy implementation, there is a need to strengthen synergies and cooperation in various places. Actively summarizing and promoting the successful experiences of pilot areas can effectively enhance the effectiveness of rural digitalization.

Second, a differentiated rural digitalization path should be built, strengthening regional synergy and linkage effects. For rural digitalization, the geographic characteristics of the county, industrial positioning, and economic base of the heterogeneous differences need to be fully considered. For implementation of the classification policy in regions with flat topography and convenient factor flows, focus should be placed on the effectiveness of digital technology in compressing spatial distances. For agriculture-dominated counties, the adaptation of digital technology to the whole industrial chain of planting, processing, and marketing should be promoted. For regions lagging behind in economic development, the focus should be on increasing the potential for late growth through digitized compensation mechanisms and policy preferences. At the regional linkage level, it is necessary to establish a cross-regional collaboration system of “complementary advantages and resource sharing.” Relying on its economic, technological, and talent advantages, the eastern region focuses on digital technology innovation and achievement transformation. The central and western regions should focus on bridging the shortcomings of digital infrastructure through financial support and policy assistance, unleashing the potential of the digital economy. At the same time, a cross-regional digital information sharing platform is being built. The cross-border flow of capital, technology, talent, and other factors should be promoted. A synergistic development pattern of “innovation-driven in the east and transformation in the central and western regions” has formed. In addition, attention needs to be given to the asymmetric response of rural innovation and entrepreneurship to digital policies. A “one-size-fits-all” approach to policy provision should be avoided, and the design of policies should precisely match the actual needs of the region.

Third, scientific and technological innovation and entrepreneurship support are two-wheel drives, systematically building a power mechanism for balanced county-level economic development and focusing on the core of digital technology innovation. According to the characteristics of different counties—e.g., agriculture dominated and industry-weak—the layout of “R&D Center + Pilot Base” innovation carriers can incentivize enterprises to invest more in technology through tax breaks, R&D subsidies, and other policies, promoting the transformation of innovation resources from “policy-driven” to “market-driven,” thus synchronizing and improving the whole chain of entrepreneurship support systems. For heterogeneous groups such as returning youths and new agricultural

business entities, a financial model of “digital asset collateral + credit loan,” a composite training course of “digital technology + industry,” and a one-stop service of a business incubator has been developed, lowering the barriers to entrepreneurship and the cost of trial and error. On this basis, a “center county–surrounding counties” innovation radiation network has been established. Through the R&D transformations carried out in eastern developed counties, the central and western counties can take advantage through technological application of the cross-domain collaboration mechanism, thus promoting the precise matching of technology, talent, and resources. Eventually, the balanced development of the county economy from a “single-point breakthrough” to an “overall leap” can be realized.

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

JP: Writing – original draft, Writing – review & editing, Conceptualization, Data curation, Formal analysis, Investigation, Supervision. JT: Formal analysis, Writing – original draft. MN: Resources, Validation, Writing – review & editing. AA: Conceptualization, Investigation, Methodology, Writing – original draft.

Funding

The author(s) declared that financial support was received for this work and/or its publication. This work was supported by the National Natural Science Foundation of China (Grant No. 72002212), the Jiangxi Province Management Science Project (Grant No. 20244BAA10076), the Science and Technology Project

References

- Aboagy-Darko, D., and Mkhize, P. (2025). Unearthing the determinants of digital innovation adoption in the agricultural sector: the role of food security awareness and agricultural experience. *Heliyon* 11:e41695. doi: 10.1016/j.heliyon.2025.e41695
- Antonelli, C. (2003). The digital divide: understanding the economics of new information and communication technology in the global economy. *Inf. Econ. Policy* 15, 173–199. doi: 10.1016/S0167-6245(02)00093-8
- Bai, C., Guan, W., Wang, D., and Chen, X. (2024). Digital village construction and the quality of life of rural residents. *Int. Rev. Econ. Finance* 96:103729. doi: 10.1016/j.iref.2024.103729
- Canwat, V., and Onakuse, S. (2022). Organic agriculture: a fountain of alternative innovations for social, economic, and environmental challenges of conventional agriculture in a developing country context. *Clean. Circ. Bioecon.* 3:100025. doi: 10.1016/j.clcb.2022.100025
- Cao, L., and Wang, G. (2024). Impact of digital finance on agricultural output: from the perspective of digital development of agriculture. *Financ. Res. Lett.* 66:105698. doi: 10.1016/j.frl.2024.105698
- Chen, L., and Gao, Y. (2025). How to implement the government subsidy policy in promoting the green development of agriculture in Hebei province? *J. Clean. Prod.* 496:145141. doi: 10.1016/j.jclepro.2025.145141
- Chen, W., and Li, J. (2025). Digital finance, rural E-commerce development and consumption upgrading. *Int. Rev. Financ. Anal.* 104:104351. doi: 10.1016/j.irfa.2025.104351
- Chen, R., Wang, Y., Wang, Q., Zhang, L., and Xiong, R. (2025). Unleashing the digital dividend: exploring how the digital economy promotes the construction of new urbanization in China's 284 prefecture-level cities? *Econ. Anal. Policy* 85, 818–834. doi: 10.1016/j.eap.2024.12.028
- CNNIC. (2023). The 52nd statistical report on China's internet development. Available online at: <https://www.cnnic.cn/n4/2023/0828/c88-10829.html> (Accessed August 28, 2023).
- Dell, M. J. E. (2010). *The persistent effects of Peru's mining mita*, vol. 78. Hoboken, NJ: John Wiley & Sons, Inc, 1863–1903.
- Deng, X., Huang, M., and Peng, R. (2024). The impact of digital economy on rural revitalization: evidence from Guangdong, China. *Heliyon* 10:e28216. doi: 10.1016/j.heliyon.2024.e28216
- Dibbern, T., Romani, L. A. S., and Massruhá, S. M. F. S. (2024). Main drivers and barriers to the adoption of digital agriculture technologies. *Smart Agric. Technol.* 8:100459. doi: 10.1016/j.atech.2024.100459
- Dimitrijević, M. S. (2023). Technological progress in the function of productivity and sustainability of agriculture: the case of innovative countries and the republic of Serbia. *J. Agric. Food Res.* 14:100856. doi: 10.1016/j.jafr.2023.100856
- Fakhraddine, M., Zerrad, N., Berhili, H., and Morchid, M. (2025). Digital transformation in Moroccan agriculture: applications, used technologies, impacts on marketing, limitations, and orientations for future research. *Smart Agric. Technol.* 11:100978. doi: 10.1016/j.atech.2025.100978

of Jiangxi Provincial Department of Education (Grant No. GJJ2502709), and the Jiangxi Institute of Fashion Technology School-level Project (Grant No. JF-LX-202514).

Conflict of interest

The author(s) declared that this work 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 author(s) declared that Generative AI was not used in the creation of this manuscript.

Any alternative text (alt text) provided alongside figures in this article has been generated by Frontiers with the support of artificial intelligence and reasonable efforts have been made to ensure accuracy, including review by the authors wherever possible. If you identify any issues, please contact us.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

Supplementary material

The Supplementary material for this article can be found online at: <https://www.frontiersin.org/articles/10.3389/fsufs.2025.1659472/full#supplementary-material>

- Food and Agriculture Organization of the United Nations. (2023). The State of Food and Agriculture 2023. Revealing the true cost of food to transform agrifood systems. Rome. doi: 10.4060/cc7724en
- Gollin, D. (2010). Agricultural Productivity and Economic Growth. *Handbook of Agricultural Economics*. 4:3825–3866. doi: 10.1016/S1574-0072(09)04073-0
- GSMA. (2023). The mobile economy 2023. Available online at: <https://www.gsma.com/solutions-and-impact/connectivity-for-good/mobile-economy/wp-content/uploads/2023/03/The-Mobile-Economy-2023.pdf>
- Hao, L., and Ki-Seong, L. (2024). The impact of economic policy uncertainty on agricultural prices: evidence from China. *Asia Glob. Econ.* 4:100100. doi: 10.1016/j.aglobe.2024.100100
- He, Z., Chen, M., and Gu, D. (2025). How digital village construction affects to the effectiveness of rural governance? — research on the NCA and QCA methods. *Cities* 156:105514. doi: 10.1016/j.cities.2024.105514
- Hu, M., Chen, P., Chen, G., and Li, Z. (2025). Spatio-temporal influencing effects and mechanisms of the digital economy on eco-urbanization in the Yangtze River Delta region. *Environ. Technol. Innov.* 37:103979. doi: 10.1016/j.eti.2024.103979
- Hu, Y., Liu, J., Zhang, S., Liu, Y., Xu, H., and Liu, P. (2024). New mechanisms for increasing agricultural total factor productivity: analysis of the regional effects of the digital economy. *Econ. Anal. Policy* 83, 766–785. doi: 10.1016/j.eap.2024.07.017
- Hu, L., Wang, C., and He, P. (2025). Sustainable development of Cuban agricultural economy: policy and practice. *Sustain. Futures* 9:100523. doi: 10.1016/j.sfr.2025.100523
- Huang, T., and Quan, Y. (2025). Narrowing the digital divide: the growth and distributional effect of internet use on income in rural China. *China Econ. Rev.* 91:102387. doi: 10.1016/j.chieco.2025.102387
- Intergovernmental Panel on Climate Change. (2023). Climate Change 2022 – Impacts, Adaptation and Vulnerability: Working Group II Contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press. doi: 10.1017/9781009325844
- Jiang, Y. (2024). Public service equalization, digital financial inclusion and the rural revitalization: evidence from Chinese 283 prefecture-level cities. *Int. Rev. Econ. Finance* 96:103648. doi: 10.1016/j.iref.2024.103648
- Jiang, Y., Han, G., and Yu, D. (2024). Digital finance and agricultural green total factor productivity: the mediating role of digital village development. *Financ. Res. Lett.* 67:105948. doi: 10.1016/j.frl.2024.105948
- Jiang, S., Zhou, J., and Qiu, S. (2022). Digital agriculture and urbanization: mechanism and empirical research. *Technol. Forecast. Soc. Change* 180:121724. doi: 10.1016/j.techfore.2022.121724
- Kitole, F. A., Mkuna, E., and Sesabo, J. K. (2024). Digitalization and agricultural transformation in developing countries: empirical evidence from Tanzania agriculture sector. *Smart Agric Technol* 7:100379. doi: 10.1016/j.atech.2023.100379
- Li, C., Luo, C., Jia, H., Yue, M., and Wu, L. (2025). Advancing agricultural economic growth through technology innovation and structural transformation: a multilevel analysis. *J. Innov. Knowl.* 10:100743. doi: 10.1016/j.jik.2025.100743
- Li, Z., and Wang, Y. (2025). Tourism industry development, rural digitalization, and green total factor productivity. *Financ. Res. Lett.* 81:107419. doi: 10.1016/j.frl.2025.107419
- Lin, Q., Jian, Y., Zhang, D., Li, J., and Mao, S. (2025). Exploring the “double-edged sword” effect of the digital economy on sustainable agricultural development: evidence from China. *Sustain. Horizons* 13:100122. doi: 10.1016/j.horiz.2024.100122
- Liu, J., and Li, F. (2025). Rural revitalization driven by digital infrastructure: Mechanisms and empirical verification. *Microelectronics Journal*. 3:103–116. doi: 10.1016/j.jdec.2025.01.002
- Lu, S., Zhuang, J., Sun, Z., and Huang, M. (2024). How can rural digitalization improve agricultural green total factor productivity: empirical evidence from counties in China. *Heliyon* 10:e35296. doi: 10.1016/j.heliyon.2024.e35296
- Ma, Q., and Shi, F. (2023). New urbanization and high-quality urban and rural development: based on the interactive coupling analysis of industrial green transformation. *Ecol. Indic.* 156:111044. doi: 10.1016/j.ecolind.2023.111044
- MIIT. (2023). China broadband development white paper (2023). Available online at: https://www.caict.ac.cn/kxyj/qwfb/bps/202401/t20240102_469295.html (Accessed December 1, 2023).
- Nhlengetfwa, N., and Mamba, S. F. (2024). Socio-economic impacts of commercialisation of agriculture in the kingdom of Eswatini: a case of Siphofaneni. *Heliyon* 10:e33722. doi: 10.1016/j.heliyon.2024.e33722
- OECD. (2022). OECD Sovereign Borrowing Outlook 2022. *OECD Publishing*. Paris. doi: 10.1787/b2d85ea7-en
- OECD. (2023). OECD Regional Outlook 2023: The Longstanding Geography of Inequalities. *OECD Publishing*. Paris. doi: 10.1787/92cd40a0-en
- Njuguna, E., Daum, T., Birner, R., and Mburu, J. (2025). Silicon Savannah and smallholder farming: how can digitalization contribute to sustainable agricultural transformation in Africa? *Agric. Syst.* 222:104180. doi: 10.1016/j.agry.2024.104180
- Peng, C., Ma, B., and Zhang, C. (2021). Poverty alleviation through e-commerce: village involvement and demonstration policies in rural China. *J. Integr. Agric.* 20, 998–1011. doi: 10.1016/S2095-3119(20)63422-0
- Radoiné, H., and Nahiduzzaman, K. M. (2025). Integrated territorial planning and digital innovation for climate-resilient urbanization in developing countries. *J. Urban Manag.* 14:10. doi: 10.1016/j.jum.2025.05.010
- Schnebelin, É., Labarthe, P., and Touzard, J.-M. (2021). How digitalisation interacts with ecologisation? Perspectives from actors of the French agricultural innovation system. *J. Rural. Stud.* 86, 599–610. doi: 10.1016/j.jrurstud.2021.07.023
- Shadkam, E., and Irannezhad, E. (2025). A comprehensive review of simulation optimization methods in agricultural supply chains and transition towards an agent-based intelligent digital framework for agriculture 4.0. *Eng. Appl. Artif. Intell.* 143:109930. doi: 10.1016/j.engappai.2024.109930
- Song, B., Robinson, G. M., Bardsley, D. K., Xue, Y., and Wang, B. (2025). Multifunctional agriculture: farm-based responses to market and government in Australia and China. *Habitat Int.* 156:103270. doi: 10.1016/j.habitatint.2024.103270
- Song, Y., Zhang, R., and Hao, Y. (2025). Digital economy, labor force transfer, and high-quality agricultural development. *Financ. Res. Lett.* 74:106692. doi: 10.1016/j.frl.2024.106692
- Swami, D., and Parthasarathy, D. (2024). Role of intrinsic motivation and government policies in adoption of sustainable agriculture practices by farmers in Maharashtra, India. *Farming Syst.* 2:100100. doi: 10.1016/j.farsys.2024.100100
- Tang, K., Cai, X., and Wang, H. (2025). Innovation capacity in urban agglomerations: the role of digital finance. *J. Innov. Knowl.* 10:100697. doi: 10.1016/j.jik.2025.100697
- Wang, H., and Li, Z. (2024). Can the digitalization level of agriculture improve its ecological efficiency under carbon constraints: evidence from China. *Heliyon* 10:e26750. doi: 10.1016/j.heliyon.2024.e26750
- Wang, S., Wang, P., Cebula, R., Foley, M., and Liang, C. (2025). Scientometric analysis of development and opportunities for research in digital agriculture innovation management. *Environ. Model. Softw.* 188:106392. doi: 10.1016/j.envsoft.2025.106392
- Wang, D., Zhou, T., and Wang, M. (2021). Information and communication technology (ICT), digital divide and urbanization: evidence from Chinese cities. *Technol. Soc.* 64:101516. doi: 10.1016/j.techsoc.2020.101516
- Wen, H., Huang, Y., and Shi, J. (2024a). Revitalizing agricultural economy through rural e-commerce? Experience from China's revolutionary old areas. *Agriculture* 14:1990. doi: 10.3390/agriculture14111990
- Wen, H., Qiu, A., and Huang, Y. (2024b). Impact of e-commerce development on rural income: evidence from counties in revolutionary old areas of China. *Econ. Labour Relat. Rev.* 35, 345–367. doi: 10.1017/elr.2024.22
- WTO. (2023). World Trade Report 2023: Reglobalization for a secure, inclusive and sustainable future. Available online at: https://www.wto.org/english/res_e/booksp_e/trade_outlook23_e.pdf
- Xu, G., Liu, J., and Zhang, M. (2024). Land property rights, spatial form, and land performance: a framework of policy performance evaluation on collective-owned construction land and evidence from rural China. *Land* 13:956. doi: 10.3390/land13070956
- Xu, Z., and Yang, J. (2025). Impact of digital finance on rural industry revitalization. *Int. Rev. Econ. Finance* 97:103820. doi: 10.1016/j.iref.2024.103820
- Xu, Q., Zhong, M., and Dong, Y. (2024). Digital finance and rural revitalization: empirical test and mechanism discussion. *Technol. Forecast. Soc. Change* 201:123248. doi: 10.1016/j.techfore.2024.123248
- Yang, C., Ji, X., Cheng, C., Liao, S., Obuobi, B., and Zhang, Y. (2024). Digital economy empowers sustainable agriculture: implications for farmers' adoption of ecological agricultural technologies. *Ecol. Indic.* 159:111723. doi: 10.1016/j.ecolind.2024.111723
- Ye, L. (2025). Digital economy and high-quality agricultural development. *Int. Rev. Econ. Finance* 99:104028. doi: 10.1016/j.iref.2025.104028
- Zhao, Q., Bao, H. X. H., and Yao, S. (2024). Unpacking the effects of rural homestead development rights reform on rural revitalization in China. *J. Rural. Stud.* 108:103265. doi: 10.1016/j.jrurstud.2024.103265
- Zhao, Y., Song, Z., Chen, J., and Dai, W. (2023). The mediating effect of urbanisation on digital technology policy and economic development: evidence from China. *J. Innov. Knowl.* 8:100318. doi: 10.1016/j.jik.2023.100318
- Zheng, S., Huang, S., and Deng, X. (2025). Digital inclusive finance and local government debt: examining the mechanism of impact on high-quality rural development from a macroeconomic perspective. *Int. Rev. Financ. Anal.* 102:104073. doi: 10.1016/j.irfa.2025.104073