科学学研究
STUDIES IN SCIENCE OF SCIENCE
中国科学学与科技政策研究会
中国科学院科技战略咨询研究院
清华大学科学技术与社会研究中心
ISSN 1003-2053 CN 11-1805/G3

Assessing the Contribution of the Digital Economy to Rural Industrial Revitalization

评估数字经济对农村产业振兴的贡献

Lim-Kuan Ho

School of Business, Western Sydney University, Australia

Correspondence: Lim-Kuan Ho; limkh00291@westernsydney.edu.au

Abstract. The digital economy has emerged as a key driver of rural industrial development in China, contributing significantly to the country's economic and social advancement. Using panel data from 30 Chinese provinces covering the period 2011–2021, this study examines the impact of the digital economy on rural industrial revitalization from a sustainable development perspective. The empirical results indicate that the digital economy significantly promotes rural industrial revitalization, while scientific and technological innovation acts as an important mediating mechanism in this relationship.The analysis further reveals notable regional heterogeneity, with the strongest impact observed in central regions, followed by western and eastern regions. Moreover, the influence of the digital economy varies across regions with different levels of rural employment. As the capacity for scientific and technological innovation improves, the positive effect of the digital economy on rural industrial development becomes increasingly pronounced. In addition, the digital economy generates spatial spillover effects, positively influencing local rural industries while exerting negative spillover effects on neighboring regions. Overall, these findings highlight the critical role of the digital economy in fostering sustainable development and promoting rural industrial revitalization in China.

Keywords: Digital economy; Rural industrial revitalization; Sustainable development; Technological innovation; Spatial spillover effects

摘要： 数字经济已成为推动中国农村产业发展的重要动力，并对国家的经济与社会进步作出了显著贡献。基于2011—2021年中国30个省份的面板数据，本文从可持续发展的视角出发，研究数字经济对农村产业振兴的影响。实证结果表明，数字经济显著促进了农村产业振兴，而科技创新在这一关系中发挥着重要的中介作用。进一步分析发现，该影响存在明显的区域异质性，其中中部地区的作用最为显著，其次为西部地区和东部地区。此外，数字经济对农村产业振兴的影响在不同农村就业水平的地区之间也存在差异。随着科技创新能力的提升，数字经济对农村产业发展的促进作用愈发显著。同时，数字经济还产生了空间溢出效应，在积极推动本地农村产业发展的同时，对邻近地区产生一定的负向溢出影响。总体而言，这些研究结果凸显了数字经济在促进可持续发展和推动中国农村产业振兴方面的重要作用。

关键词： 数字经济；农村产业振兴；可持续发展；技术创新；空间溢出效应，并在学科领域中较为常用

Received: 23 January 2026 **Revised:** 20 February 2026 **Accepted:** 12 March 2026 **Published:** 30 March 2026

Citation: Ho, L.-H (2026). Assessing the Contribution of the Digital Economy to Rural Industrial Revitalization [评估数字经济对农村产业振兴的贡献]. *Studies in Science of Science*, 44(3), 230–247.

1. Introduction

China is one of the world's leading agricultural producers. Since the implementation of the reform and opening-up policies in 1978, rapid industrialization and urbanization have significantly reshaped agricultural production systems, farmers' livelihoods, and rural social structures. Nevertheless, as noted by Park (1932), many social challenges in Eastern societies are closely related to rural issues. China continues to face structural problems such as a large population, weak rural foundations, an underdeveloped agricultural base, and a persistent urban–rural development gap (Liu et al., 2020; Wang et al., 2024a, 2024b, 2024c). In addition, extensive rural development patterns, relatively low economic efficiency, and environmental pollution—together with the long-standing urban–rural dual structure and city-centered development strategy—have increasingly constrained the sustainable development of China's economy (Tang & Chen, 2022). Consequently, improving agricultural productivity and raising farmers' incomes remain key priorities for the Chinese government (Shen et al., 2022).

To address uneven and insufficient rural development, China introduced the Rural Revitalization Strategy in 2017, which has since accelerated the development of rural industries. Industrial development is considered a fundamental driver of rural transformation. In 2020, the government released the National Rural Industry Development Plan (2020–2025), emphasizing the central role of rural industrial growth in achieving revitalization objectives. These initiatives have contributed to strengthening China's agricultural sector, narrowing the urban–rural income gap, and enhancing farmers' livelihoods. According to the National Bureau of Statistics of China, the value added by agriculture and related sectors reached 19,569.2 billion yuan in 2022, accounting for 16.24% of GDP. In 2023, the per capita disposable income of urban and rural residents was 51,821 yuan and 21,691 yuan, respectively, reducing the income ratio to 2.39 and indicating a gradual narrowing of the urban–rural income gap.

Recent advancements in digital technologies have driven the rapid expansion of the digital economy, which exceeded 55 trillion yuan in China by 2023. Digitalization has increasingly influenced multiple sectors, including environmental governance (Du et al., 2023; Yi et al., 2022; Lee & Wang, 2022; Shahbaz et al., 2024), financial development (Du et al., 2023), public governance (Zhao et al., 2023), corporate transformation (Lee et al., 2023; Heredia et al., 2022; Gao et al., 2023; Zhang et al., 2023a, 2023b, 2023c; Huo & Wang, 2022), urban development (Wang et al., 2024a, 2024b, 2024c), and rural security (Wang et al., 2024a, 2024b, 2024c). In rural areas, policy initiatives such as the Digital Rural Development Action Plan (2022–2025) and the Digital Rural Construction Guidelines 2.0 have fostered favorable conditions for rural industrial growth. Digital technologies are increasingly integrated into agricultural production and distribution systems. For instance, rural e-commerce retail sales reached 2.17 trillion yuan in 2022, while the number of Taobao villages increased from 2,118 in 2017 to 7,780 in 2022. These developments demonstrate how the digital economy reshapes rural economic structures and promotes the transformation and upgrading of rural industries (Zhang et al., 2023a, 2023b, 2023c).

Existing studies primarily examine the role of the digital economy in agricultural development, while empirical evidence on how digitalization drives rural industrial revitalization remains limited. In particular, the mediating role of scientific and technological innovation in this relationship requires further investigation. Moreover, the spatial spillover effects of the digital economy on rural industrial revitalization have received limited scholarly attention. Using panel data from 30 Chinese provinces during 2011–2021, this study investigates the relationship between the digital economy and rural industrial revitalization. Theoretically, it extends the literature by examining mediation, heterogeneity, threshold, and spatial spillover effects. Practically, the findings provide policy insights for promoting rural innovation, expanding employment opportunities, optimizing urban–rural resource allocation, and supporting the sustainable development of rural economies.

2. Materials and Methods

Rural industries play a fundamental role in stimulating income growth and economic development in rural areas. The revitalization of rural industries strengthens the self-sustaining capacity of rural communities while creating employment opportunities that increase farmers' income. The digital economy provides new opportunities for rural industrial transformation through its advantages in cross-temporal and spatial information dissemination, data-driven decision-making, low transaction costs, rapid circulation of information, advanced technological applications, and strong industrial penetration. These characteristics help address persistent challenges in rural development, including inefficient allocation of production factors, limited market information, and the low added value of agricultural products (Zhao et al., 2023; Guo et al., 2023). In addition to its direct effects on rural industrial development, the digital economy can indirectly influence rural industries by strengthening regional scientific and technological innovation capabilities. According to Metcalfe's Law, the value of a network increases proportionally with the square of its nodes, implying that larger digital networks generate stronger economic and social impacts. Consequently, the influence of the digital economy on rural industrial revitalization may exhibit nonlinear dynamics and spatial spillover effects. While traditional rural development or resource dependence theories provide insights into resource allocation and development pathways, they are largely rooted in conventional agricultural production systems and therefore cannot fully explain the role of technological innovation and digitalization in shaping modern rural industries. In contrast, sustainable development theory offers a broader framework to explain the long-term contribution of the digital economy to rural industrial development by emphasizing the balance among economic growth, environmental sustainability, and social welfare.

Within the technological-economic paradigm perspective, the digital economy represents a transformative production system driven by intelligent technologies, network connectivity, and data as core production factors (Goodell et al., 2023a, 2023b; Hunjra et al., 2024). Unlike traditional production inputs such as land, labor, and capital, data possess unique characteristics—including replicability, shareability, and low marginal cost—that allow them to reshape rural industrial structures and enhance industrial intensification, specialization, environmental sustainability, integration, and operational efficiency. First, digital technologies significantly improve the intensification of rural industries by overcoming traditional resource constraints and enabling more efficient agricultural production. Digital agricultural technologies support mechanization and large-scale operations, thereby improving productivity, optimizing agricultural models, and increasing product quality and output (Struik & Kuyper, 2017). Second, the digital economy promotes specialization by strengthening the division of labor across production processes and enabling the development of supporting industries such as rural e-commerce, logistics, packaging, and marketing. Farmers' cooperatives and digital platforms further facilitate specialized services such as product processing, storage, transportation, and technical assistance. Third, digitalization contributes to the greening of rural industries. Due to their relatively low resource consumption and environmental impact, digital technologies serve as an important driver of environmentally sustainable agricultural practices (Ma & Zhu, 2022; Xu et al., 2022). Fourth, the digital economy encourages the integration of rural industries by enabling stronger connections between agriculture and emerging sectors such as e-commerce, rural tourism, and digital services. Through improved connectivity and data sharing, digital technologies facilitate coordination across production, processing, distribution, and marketing systems (Zhang et al., 2023a, 2023b, 2023c). Finally, digitalization improves the overall efficiency of rural industries by reducing information asymmetry, improving resource allocation, and enhancing total factor productivity. Technologies such as the Internet and big data eliminate "information islands" created by geographical barriers, allowing rural production resources and data to be shared across regions and production systems (Pan et al., 2022; Li et al., 2022). Based on these mechanisms, the digital economy is expected to serve as a key driver of rural industrial transformation.

Hypothesis 1. *The digital economy has a positive impact on rural industrial revitalization.*

In addition to its direct influence, the digital economy may also promote rural industrial revitalization through the enhancement of scientific and technological innovation capabilities. Technological innovation plays a crucial role in accelerating the application of knowledge in production activities while reducing the costs associated with information search and technological adoption. Digital platforms facilitate the rapid diffusion of innovative knowledge and support the integration of new technologies into rural industrial systems (Pan et al., 2022). As technological progress continues, particularly in fields such as big data analytics, artificial intelligence, and the Internet of Things (IoT), rural industries can adopt more intelligent and efficient production methods. These technologies improve operational efficiency, promote innovation, and stimulate economic diversification in rural areas. As a technology-intensive economic form, the digital economy encourages rural industries to continuously adopt advanced technologies, thereby enhancing productivity and competitiveness (Zhang et al., 2023a, 2023b, 2023c). Digital technologies also reshape agricultural value chains by improving the quality and functionality of agricultural products and transforming the processes of production, processing, and distribution. Furthermore, technological innovation influences consumer demand and industrial structure by shifting consumption patterns from price-oriented demand toward more personalized and experiential products. The development of e-commerce platforms facilitates the expansion of agricultural product markets, while advances in logistics, payment technologies, and financial technology improve supply chain efficiency and increase access to rural financial services (Rijswijk et al., 2021). These transformations encourage the integration of agriculture with modern service sectors and contribute to the formation of diversified "Agriculture +" industrial models. Consequently, technological innovation strengthens the innovation capacity and competitiveness of rural industries and promotes the sustainable development of rural economies.

Hypothesis 2. *The digital economy promotes rural industrial revitalization by enhancing scientific and technological innovation capabilities.*

The impact of the digital economy on rural industrial revitalization may also exhibit nonlinear characteristics. Existing literature provides limited discussion of how digitalization influences rural industries across different stages of technological development. The role of the digital economy may vary depending on the level of scientific and technological innovation capacity, which may generate threshold effects. China's vast territory and heterogeneous regional conditions—including differences in economic development, governance quality, market environments, and digital infrastructure—create diverse development patterns that influence how digitalization affects rural industries (Peng & Dan, 2023). During the early stages of digital economic development, digital networks remain relatively small, innovation capacity is limited, and the costs of promoting rural industrial transformation are relatively high. As digital infrastructure expands and innovation capabilities improve, network scale increases and the economic value of digital technologies becomes more significant. With a growing number of internet users and stronger digital connectivity, network effects become more pronounced, marginal costs decrease, and marginal benefits increase, leading to accelerated development of rural industries.

Hypothesis 3. *The positive impact of the digital economy on rural industrial revitalization increases as scientific and technological innovation capabilities improve.*

Furthermore, the digital economy may generate spatial spillover effects that influence rural industries beyond local regions. Spatial economic perspectives suggest that digital technologies can transcend geographical boundaries and facilitate the flow of information, knowledge, and innovation across regions. Previous studies have demonstrated that infrastructure and technological development can generate significant spatial spillovers. For example, Serdar Yilmaz et al. (2002) found that telecommunications infrastructure investment produced positive spillover effects on economic output in neighboring states, while Sun et al. (2021) showed that technological innovation in one country could improve the energy efficiency performance of neighboring countries through knowledge diffusion. As digital technologies expand, the digital economy enhances the connectivity of cyberspace and broadens the spatial allocation of innovative resources. Digital networks reduce temporal and spatial barriers, expand interregional economic interactions, and facilitate the formation of interconnected rural industrial chains. In addition, digital economic development attracts and cultivates digital technology talent, while the mobility of human capital creates channels for the geographical diffusion of knowledge and innovation (Jiang et al., 2022). These processes strengthen interregional linkages and promote collaborative rural industrial development.

Hypothesis 4. *The digital economy influences the development of rural industries in neighboring regions through spatial spillover effects.*

This study develops an econometric framework to examine the relationship between digital economy development and rural industrial revitalization. To test the direct impact of digital economy development on rural industrial revitalization, the baseline model is constructed as follows:

$$\mathrm{RIR}_{it} = \alpha^0 + \alpha^1 \mathrm{DED}_{it} + \alpha^2 \mathrm{Control}_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \qquad (1)$$

In Equation (1), RIR represents the level of rural industrial revitalization, DED denotes the level of digital economy development, and Control refers to a set of control variables. λ_i and γ_t represent province fixed effects and time fixed effects, respectively, while ε_it denotes the random error term. The subscripts i and t represent province and year.

To further investigate whether technological innovation capability serves as a mediating mechanism between the digital economy and rural industrial revitalization, this study follows the mediation analysis approach proposed by Wen et al. (2004). Two additional regression models are constructed. The first examines the impact of digital economy development on technological innovation capability (YZ), while the second assesses the joint impact of digital economy development and technological innovation capability on rural industrial revitalization. The models are specified as follows:

$$\mathrm{RIR}_{it} = \alpha^0 + \alpha^1 \mathrm{DED}_{it} + \alpha^2 \mathrm{Control}_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \qquad (2)$$

$$YZ_{it} = \beta^0 + \beta^1 DED_{it} + \beta^2 Control_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (3)$$

$$RIR_{it} = \gamma^0 + \gamma^1 DED_{it} + \gamma^2 YZ_{it} + \gamma^3 Control_{it} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (4)$$

In these equations, YZ represents technological innovation capability as the mediating variable. The models allow the decomposition of the direct and indirect effects of the digital economy on rural industrial revitalization.

Considering Metcalfe's Law—which suggests that the value of the Internet increases with the number of users—the impact of the digital economy on rural industrial revitalization may exhibit nonlinear characteristics. To capture this potential nonlinear relationship, a panel threshold model is constructed:

$$RIR_{it} = \varphi^0 + \varphi^1 DED_{it} \times I(Adj_{it} \leq \theta) + \varphi^2 DED_{it} \times I(Adj_{it} > \theta) + \varphi_{cControl_{it}} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (5)$$

In Equation (5), Adj_it represents the threshold variable, while I(·) denotes an indicator function that takes the value of 1 when the condition in the brackets is satisfied and 0 otherwise. Equation (5) represents a single-threshold model, which can be extended to multiple threshold models based on the results of threshold tests.

To further explore the spatial spillover effects of the digital economy on rural industrial revitalization, spatial interaction terms are introduced into the baseline model, leading to the construction of the following spatial panel econometric model:

$$RIR_{it} = \alpha^0 + \rho WRIR_{it} + \varphi^1 WDED_{it} + \alpha^1 DED_{it} + \varphi_{cWControl_{it}} + \alpha_{cControl_{it}} + \lambda_i + \gamma_t + \varepsilon_{it} \quad (6)$$

In Equation (6), ρ denotes the spatial autoregressive coefficient, W represents the spatial weight matrix, and α_1 captures the direct effect of digital economy development on rural industrial revitalization. ϕ_1 and ϕ_c represent the coefficients of the spatial interaction terms for the core explanatory variable and control variables, respectively. The spatial weight matrix measures the degree of spatial association among regions and is used to capture spatial dependence across provinces.

Table 1. Spatial Weight Matrix

Matrix	Explanation
Economic Weight Matrix (W1)	GDP_i - GDP_j
Economic Geography Weight Matrix (W2)	GDP_i - GDP_j

The explained variable in this study is the level of rural industrial revitalization (RIR). According to the "Guiding Opinions on Promoting the Revitalization of Rural Industries" issued by the Chinese government in 2019, rural industries are defined as industries rooted in county-level economies that rely on agricultural and rural resources, with farmers as the primary participants and the integrated development of primary, secondary, and tertiary industries as the development pathway. These industries are characterized by strong regional features, active innovation and entrepreneurship, diversified business forms, and close interest linkages among stakeholders. Rural industrial development therefore extends beyond traditional agricultural production and emphasizes the integrated development of agriculture, processing, and service industries. Based on this concept, this study constructs an evaluation index system for rural industrial revitalization from five dimensions: intensification, specialization, greening, integration, and efficiency. The entropy method is applied to determine indicator weights and construct a comprehensive rural industrial revitalization index.

Table 2. The Level of Development of Rural Industrial Revitalization

Primary Indicator	Secondary Indicator	Indicator Description	Data Sources
Industrial Intensification	Yield per unit area of grain crops	–	NBS, China Statistical Yearbook
	Development level of agricultural machinery	Ratio of total agricultural machinery power to total sown area	NBS
Industrial Specialization	Machine sowing area	Natural logarithm of machine sowing area	China Rural Statistical Yearbook
	Rural professional cooperatives	Natural logarithm of farmers' cooperatives	Rural Cooperative Economic Statistical Yearbook
Industrial Greening	Pesticide usage per unit output	Pesticide usage / total agricultural output value	NBS
	Water-saving irrigation area	Natural logarithm of irrigation area	China Statistical Yearbook
Industrial Integration	Value added of agriculture, forestry, animal husbandry and fishery	Value added of primary industry	NBS
Industrial Efficiency	Land productivity	Ratio of agricultural output value to sown area	NBS
	Labor productivity	Agricultural output / employment in primary industry	China Population and Employment Statistical Yearbook

The core explanatory variable is the level of digital economy development (DED). The concept of the digital economy was first introduced by Tapscott (1996), referring to a modern economic form driven by information, knowledge, and digital technologies that penetrate various sectors such as production, management, and circulation (Tan et al., 2024; Peng & Tao, 2022). With the rapid advancement of internet technologies, the digital economy has created new opportunities for economic and social activities in areas such as information exchange, knowledge transfer, e-commerce, healthcare, and education (Castellacci & Tveito, 2018). In this study, the digital economy development index is constructed from three dimensions: digital environment, digital industrialization, and industrial digitization.

Table 4. Description of Mediating Variables

Variables	Description	Data Sources
YZ	Number of R&D staff	China Statistical Yearbook on Science and Technology
	Patent authorizations	NBS

The mediating variable is scientific and technological innovation capability (YZ). This study measures technological innovation capability using indicators such as the number of R&D personnel and the number of patent authorizations. The entropy method is again employed to determine the weights of each indicator and construct a comprehensive technological innovation capability index.

Table 5. Description of Control Variables

Variables	Description	Data Sources
Third	Ratio of tertiary industry added value to GDP	NBS
Energy	Electricity consumption proportion	NBS
Traffic	Logarithm of freight volume	NBS
Town	Urban population proportion	NBS
Open	Import and export proportion in GDP	NBS

To ensure robustness, several control variables that may influence rural industrial revitalization are included in the model. These variables include the development level of the tertiary industry (Third), energy consumption (Energy), freight transport capacity (Traffic), urbanization level (Town), and the level of economic openness (Open). These factors reflect key structural characteristics of regional economic development that may affect rural industrial transformation.

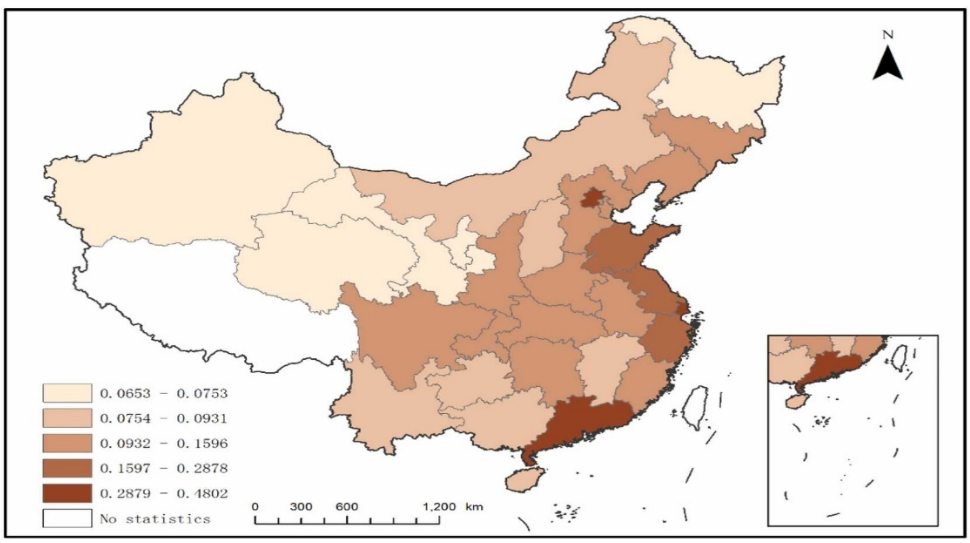

Figure 1. Regional distribution of rural industrial revitalization index.

The empirical analysis is based on panel data from 30 Chinese provinces covering the period 2011–2021. Tibet, Hong Kong, Macao, and Taiwan are excluded due to substantial data limitations. The data are primarily obtained from the National Bureau of Statistics of China, the China Statistical Yearbook, and the China Rural Statistical Yearbook. Missing observations for certain years are supplemented using linear interpolation to maintain the continuity and completeness of the dataset.

3. Result

Table 6. Test Results for Regression Model Selection

Test Method	Test Results
F-test	11.77***
Hausman test	103.39***

The benchmark regression analysis is conducted to examine the relationship between digital economy development and rural industrial revitalization. Prior to estimating the baseline model, both the F-test and Hausman test are employed to determine the appropriate econometric specification. The F-test results indicate that the fixed-effects model is preferable to the pooled model, as the corresponding p-value is 0.0000. Furthermore, the Hausman test yields a p-value of 0.0000, rejecting the null hypothesis that the random-effects estimator is consistent. Consequently, the fixed-effects model is adopted for the subsequent empirical analysis. The test results are presented in Table 6.

Table 7. Benchmark Regression Results

Variables	RIR (1)	RIR (2)
DED	0.4754***	0.6201***
Third	–	0.2047
Energy	–	0.8090
Traffic	–	0.0658*
Town	–	0.5208
Open	–	−0.0097
Constant	−0.0332	−1.3090**
N	330	330
R^2	0.7704	0.7833
Regional effect	YES	YES
Time effect	YES	YES

The benchmark regression results, reported in Table 7, demonstrate that the estimated coefficient of digital economy development (DED) is significantly positive. Specifically, a one-unit increase in the digital economy development index is associated with a 62.01% increase in rural industrial revitalization. After controlling for additional variables, the positive relationship remains statistically significant at the 1% level. These findings provide strong empirical evidence that the digital economy plays a significant role in promoting rural industrial revitalization, thereby supporting Hypothesis 1.

Table 8. Mechanism Test Results

Variables	RIR (1)	YZ (2)	RIR (3)
DED	0.6201***	0.3562***	0.4300***
YZ	–	–	0.5330***
Third	0.2047	−0.0327	0.2222
Energy	0.8090	0.1457	0.7319
Traffic	0.0658*	0.0248	0.0527
Town	0.5208	0.9057***	0.0430
Open	−0.0097	−0.0108	−0.0039
N	330	330	330
R^2	0.7833	0.9935	0.7917

Regional FE	YES	YES	YES
Time FE	YES	YES	YES

To further explore the underlying mechanism, this study examines whether scientific and technological innovation capability (YZ) acts as a mediating variable in the relationship between the digital economy and rural industrial revitalization. The mediation analysis results are presented in Table 8. The results confirm that digital economy development significantly promotes rural industrial revitalization. In addition, the digital economy also exerts a significant positive influence on scientific and technological innovation capability at the 1% significance level. When both variables are included in the regression model, the coefficient of digital economy development decreases from 0.6201 to 0.4300 while remaining statistically significant. This reduction indicates that technological innovation capability partially mediates the relationship between the digital economy and rural industrial revitalization. In other words, the digital economy promotes rural industrial revitalization partly by enhancing regional technological innovation capacity. These results confirm the existence of the proposed mechanism and support Hypothesis 2.

Table 9. Robustness Test Results

Variables	Delete Municipalities	Replace Explained Variable	Replace Explanatory Variable
DED	1.4115***	0.4757***	0.3515***
Third	0.2062	0.1971	0.2260
Energy	−0.2444	0.7973	0.7799
Traffic	0.0982**	0.0650*	0.0733*
Town	−0.7744**	0.5219*	0.4708*
Open	0.0201	−0.0087	−0.0484
N	286	330	330
R^2	0.8451	0.7718	0.7013

To ensure the reliability of the empirical results, several robustness tests are conducted. First, considering the substantial differences in policy support, economic strength, and development conditions between China's municipalities and other provinces, the four municipalities—Beijing, Tianjin, Shanghai, and Chongqing—are excluded from the sample. The regression results using the remaining 26 provinces remain consistent with the baseline findings. The coefficient of the digital economy remains significantly positive at the 1% level, indicating that the main results are not driven by these special administrative regions. This confirms that the positive effect of digital economy development on rural industrial revitalization is robust across a broader regional context.

Second, variable substitution tests are conducted to further examine the robustness of the results. Specifically, pesticide usage per unit of output value is replaced with plastic film usage per unit of output value, while optical cable line density is replaced with mobile phone base station density. The regression results remain stable after these substitutions. The coefficients of digital economy development remain significantly positive at the 1% level, indicating that the empirical findings are not sensitive to the selection of specific measurement indicators. These results further confirm the robustness and reliability of the study's conclusions.

Table 10. Endogeneity Test Results

Variables	First Stage	Second Stage
L.DED	0.8703***	–
DED	–	0.7832**
Kleibergen-Paap LM	52.175	
Kleibergen-Paap Wald F	318.372	
R^2	0.9775	0.5983
N	330	330

In addition, an endogeneity test is performed to address potential reverse causality and omitted variable bias. Following common econometric practice, the one-period lag of digital economy development is used as an instrumental variable, and the instrumental variable two-stage least squares (IV-2SLS) method is applied.

Table 11. Heterogeneity Test Results

Variables	East	Central	West	Large Employment	Small Employment
DED	0.5270*	0.8106***	0.4707***	1.4716***	−0.0830
Third	−0.2014	1.054*	−0.0104	−1.5375	0.0200
Energy	4.5504	−2.1531	0.7873	0.6109	0.4573
Traffic	0.1285	−0.0085	0.0228	0.1835	0.0226
Town	2.3265	0.3773	0.2684	−0.8969	0.0819
Open	−0.0424	−0.1197	0.0226	0.4317**	−0.0820
N	121	88	121	110	220

The digital economy exhibits a strong path dependence, meaning that past digital economy development significantly influences current digital economy performance. Therefore, the lagged digital economy variable satisfies the relevance condition of an instrumental variable. At the same time, the lagged digital economy variable is unlikely to be directly influenced by current rural industrial revitalization, thereby satisfying the exogeneity condition. The results presented in Table 10 show that the Kleibergen–Paap rk LM statistic is significant at the 1% level, indicating that the model does not suffer from under-identification. Furthermore, the Kleibergen–Paap rk Wald F statistic exceeds the conventional threshold of 10, suggesting that weak instrumental variables are not a concern. After addressing potential endogeneity issues, the positive impact of the digital economy on rural industrial revitalization remains statistically significant, confirming the robustness of the baseline conclusions.

Given the significant regional disparities in China in terms of economic development, resource endowments, and digital infrastructure, further analysis is conducted to examine regional heterogeneity. China's provinces are divided into eastern, central, and western regions to evaluate whether the effect of the digital economy differs across regions. The results indicate substantial regional differences in the impact of digital economy development on rural industrial revitalization, reflecting variations in economic structure, technological capabilities, and development conditions across regions. These findings highlight the importance of considering regional heterogeneity when formulating policies aimed at promoting digital-driven rural industrial development.

To further examine whether the digital economy promotes rural industrial revitalization through nonlinear dynamics, this study employs a panel threshold model using scientific and technological innovation capability (YZ) as the threshold variable. Following the threshold estimation procedure proposed by Hansen (1999), the bootstrap method with 500 replications is applied to test the presence of threshold effects. The results indicate that the technological innovation capability variable significantly passes the double-threshold test, suggesting the existence of nonlinear effects in the relationship between the digital economy and rural industrial revitalization. Consequently, a double-threshold regression model is estimated, and the results are presented in Table 12.

Table 12. Threshold Regression Results

Variable	**Coefficient**
Threshold q1	0.7968
Threshold q2	0.8786
DED (YZ < q1)	0.0796
DED (q1 < YZ < q2)	0.4936*
DED (YZ > q2)	0.8330***
R^2	0.7996
N	330

The findings show that the impact of digital economy development on rural industrial revitalization varies across different levels of technological innovation capability. When technological innovation capability is below the first threshold value of 0.7968, the coefficient of the digital economy is 0.0796 and statistically insignificant. This may be attributed to the early stage of digital integration with rural industries, where management remains relatively extensive, the payback period of digital investments is longer, and trial-and-error costs are relatively high. Moreover, the digital economy at this stage is not sufficiently developed to provide strong incentives for digital transformation in rural industries. When the level of technological innovation capability lies between the first threshold (0.7968) and the second threshold (0.8786), the coefficient of the digital economy increases to 0.4936 and becomes significant at the 10% level. This result indicates that as the digital economy continues to expand and digital technologies become more integrated with traditional rural industries, the revitalization of rural industries becomes increasingly evident. When technological innovation capability exceeds the second threshold value of 0.8786, the coefficient of the digital economy rises further to 0.8330 and is significant at the 1% level. A typical example is the development of "Taobao Villages," a digital entrepreneurship model adopted by many Chinese farmers. In its early stage, only a limited number of individuals participated in e-commerce activities and the number of Taobao villages remained small. However, with government support and the continuous diffusion of digital technologies, the clustering and diffusion effects of Taobao villages have strengthened over time, leading to the rapid expansion of rural e-commerce networks (Li et al., 2023). These findings demonstrate that the digital economy exhibits nonlinear characteristics in promoting rural industrial revitalization, and that the strength of this effect increases with improvements in technological innovation capability. Therefore, Hypothesis 3 is supported.

In addition to nonlinear dynamics, the digital economy may also generate spatial spillover effects on rural industrial revitalization. To test for spatial dependence, this study calculates the Moran's I index for both digital economy development and rural industrial revitalization using the economic geography weight matrix (W2). The results presented in Table 13 show that the Moran's I index of the digital economy is significantly positive, while the Moran's I index of rural industrial revitalization is mostly positive and statistically significant. These results indicate that both variables exhibit spatial autocorrelation and spatial clustering, suggesting that regional economic activities related to digital development and rural industrial growth are spatially interconnected.

Table 13. Moran's I IndexMoran's I Index

Year	Digital Economy (I)	Z	P-value	Rural Industry Revitalization (I)	Z	P-value
2011	0.442	4.129	0.000	0.144	1.535	0.002
2015	0.329	3.270	0.001	0.124	1.360	0.080
2018	0.273	2.758	0.003	0.160	1.738	0.041
2021	0.276	2.829	0.002	0.180	1.976	0.024

Before conducting spatial econometric estimation, several diagnostic tests are performed to determine the appropriate spatial model specification. The Lagrange Multiplier test results indicate the presence of spatial dependence under different spatial weight matrices, confirming the suitability of spatial econometric models. Furthermore, the Likelihood Ratio test and Wald test strongly reject the null hypothesis that the Spatial Durbin Model (SDM) can be simplified into either the Spatial Autoregressive Model (SAR) or the Spatial Error Model (SEM). In addition, the Hausman test results support the use of a fixed-effects specification. Considering the Log-likelihood values of alternative models, the spatial-temporal two-way fixed-effects Spatial Durbin Model is selected as the most appropriate specification for the analysis.

T**able 15.** Spatial Durbin Model ResultsModel Results

Test	W1	W2
LM-lag	12.161	34.991
LM-error	77.904	76.308
Wald-lag	17.260	16.790
Wald-error	14.770	14.371
Hausman	26.015	49.780

The regression results based on the Spatial Durbin Model using both the economic weight matrix (W1) and the economic geography weight matrix (W2) are reported in Table 15. The results indicate that digital economy development has a significantly positive direct effect on rural industrial revitalization at the 1% significance level under both spatial weight matrices. For example, under matrix W1, a one-unit increase in the digital economy index increases the rural industrial revitalization index by 0.5278 units. However, the spatial interaction term between the digital economy and the spatial weight matrix reveals that the spillover effect of the digital economy on neighboring regions' rural industries is negative and statistically significant under W1, while it is insignificant under W2. This suggests that while digital economy development promotes local rural industrial revitalization, it may simultaneously exert a negative spillover effect on surrounding regions.

The spatial autocorrelation coefficient further shows that rural industrial revitalization exhibits a positive spillover effect under W1 but an insignificant negative effect under W2, indicating substantial spatial heterogeneity in rural industrial development across regions. One possible explanation is the presence of a "siphon effect." Under market economy conditions, factor resources such as capital, technology, and human talent tend to flow toward regions with stronger economic development and better growth prospects. As cross-regional resource mobility increases, economically stronger regions may attract more resources from neighboring areas, thereby strengthening their own rural industries while weakening the development potential of surrounding regions (Chen & Wang, 2022). Compared with developed Western countries, China's digital economy started relatively late and exhibits significant disparities in digital infrastructure and technological development across regions. Areas with higher concentrations of digital platforms and technologies possess stronger competitive advantages and are more likely to attract high-quality production factors from neighboring areas (Wang et al., 2024a, 2024b, 2024c). This concentration of resources reflects the typical "siphon effect" observed in regional economic development, whereby economically stronger regions attract resources from surrounding areas, intensifying regional disparities (Xu et al., 2024). Although similar effects may occur in developed countries, their more advanced digital infrastructure and stronger connectivity often allow digital technologies to generate positive spillovers that promote coordinated rural development across regions (Kirschning & Mrożewski, 2024).

Following the approach proposed by Partridge et al. (2012), this study further decomposes the Spatial Durbin Model results into direct, indirect, and total effects. The direct effect results are highly consistent with the baseline regression results, indicating that the digital economy significantly promotes rural industrial revitalization within the local region. For example, under matrix W2, a one-unit increase in the digital economy index leads to a 0.4872-unit increase in the rural industrial revitalization index. The spillover effect, calculated as the difference between total and direct effects, is largely consistent with the spatial interaction term estimates. Under matrix W1, the spillover effect of the digital economy is significantly negative, indicating that an increase of one unit in the digital economy level in neighboring regions reduces the local rural industrial revitalization index by approximately 2.0048 units. These results confirm that the spatial spillover effect of the digital economy is primarily negative, reflecting the siphon effect whereby factor resources concentrate in regions with stronger economic and digital development. From the perspective of total effects, the coefficients display both positive and negative values across different spatial matrices, indicating that digital economy development in one region may simultaneously promote and inhibit rural industrial revitalization in other regions. Overall, the empirical findings support Hypothesis 4.

4. Conclusions and Implications

This study investigates the relationship between digital economy development and rural industrial revitalization using panel data from 30 Chinese provinces over the period 2011–2021. By constructing comprehensive indices for both the digital economy and rural industrial revitalization, the empirical analysis provides new insights into the mechanisms and impacts through which digital transformation contributes to rural development. The results indicate that the digital economy significantly promotes rural industrial revitalization, supporting Hypothesis 1. In addition, technological innovation capability plays an important mediating role in this relationship. The digital economy enhances rural industrial revitalization partly by strengthening regional technological innovation capacity, thereby confirming Hypothesis 2.The findings further reveal substantial heterogeneity in the impact of the digital economy across regions. From a geographical perspective, the digital economy exerts a stronger effect on rural industrial revitalization in central and western China than in eastern regions, which may reflect differences in resource endowments, development stages, and regional economic structures. Moreover, regions with higher levels of rural individual employment demonstrate stronger digital economy effects, whereas provinces with smaller rural employment scales have yet to fully benefit from digital transformation. The results also confirm the existence of nonlinear dynamics: as technological innovation capability improves, the positive impact of the digital economy on rural industrial revitalization becomes increasingly pronounced. In the early stages of digital development, adoption costs and technical barriers limit the role of the digital economy in rural areas. However, once technological innovation reaches a critical threshold, the digital economy generates rapid growth and significantly accelerates rural industrial transformation, supporting Hypothesis 3.

In addition to these nonlinear effects, the digital economy also generates spatial spillover effects across regions. Digital development can facilitate information sharing, market expansion, and interregional industrial cooperation, thereby promoting rural industrial revitalization in local regions. At the same time, rapid digital development in certain regions may attract resources such as capital, technology, and human talent from neighboring areas, resulting in a "siphon effect" that weakens rural industrial development in surrounding regions. These findings confirm Hypothesis 4 and highlight the complex spatial interactions associated with digital economic development. Based on these findings, several policy implications emerge. First, governments should increase investment in digital infrastructure and technological innovation to ensure reliable network coverage and accelerate digital transformation in rural areas. Second, enterprises should actively engage in technological innovation by strengthening collaboration with universities, research institutes, and other knowledge institutions to promote technology transfer, talent development, and the commercialization of research outcomes. Finally, rural residents should be encouraged to enhance their digital literacy through training programs that improve their ability to utilize digital technologies. With appropriate institutional support, rural communities can leverage digital tools to develop innovative business models and expand income-generating opportunities. Overall, the digital economy offers substantial potential for promoting sustainable rural development, provided that digital infrastructure, innovation capacity, and human capital are developed in a coordinated manner.

References

Castellacci, F., & Tveito, V. (2018). Internet use and well-being: A survey and a theoretical framework. *Research Policy, 47*(1), 308–325. https://doi.org/10.1016/j.respol.2017.11.007

Chen, M., & Long, Y. A. (2024). Empowering rural revitalization: Unleashing the potential of e-commerce for sustainable industrial integration. *Journal of the Knowledge Economy*, 1–19. https://doi.org/10.1007/s13132-024-01813-3

Chen, L., & Wang, K. (2022). The spatial spillover effect of low-carbon city pilot scheme on green efficiency in China's cities: Evidence from a quasi-natural experiment. *Energy Economics, 110*, 106018. https://doi.org/10.1016/j.eneco.2022.106018

Du, Q., Zhou, F., Yang, T., & Du, M. (2023). Digital financial inclusion, household financial participation and well-being: Micro-evidence from China. *Emerging Markets Finance and Trade, 59*(6), 1782–1796. https://doi.org/10.1080/1540496X.2022.2153592

Gao, D., Yan, Z., Zhou, X., & Mo, X. (2023). Smarter and prosperous: Digital transformation and enterprise performance. *Systems, 11*(7), 329. https://doi.org/10.3390/systems11070329

Goodell, J. W., Nammouri, H., Sâadaoui, F., & Ben Jabeur, S. (2023a). Carbon allowances amid climate change concerns: Fresh insights from wavelet multiscale analysis. *Finance Research Letters, 55*, 103871. https://doi.org/10.1016/j.frl.2023.103871

Goodell, J. W., Yadav, M. P., Ruan, J., Abedin, M. Z., & Malhotra, N. (2023b). Traditional assets, digital assets and renewable energy: Investigating connectedness during COVID-19 and the Russia–Ukraine war. *Finance Research Letters, 58*, 104323. https://doi.org/10.1016/j.frl.2023.104323

Guo, B., Wang, Y., Zhang, H., Liang, C., Feng, Y., & Hu, F. (2023). Impact of the digital economy on high-quality urban economic development: Evidence from Chinese cities. *Economic Modelling, 120*, 106194. https://doi.org/10.1016/j.econmod.2023.106194

Hansen, B. E. (1999). Threshold effects in non-dynamic panels: Estimation, testing, and inference. *Journal of Econometrics, 93*(2), 345–368. https://doi.org/10.1016/S0304-4076(99)00025-1

Heredia, J., Castillo-Vergara, M., Geldes, C., Gamarra, F. M. C., Flores, A., & Heredia, W. (2022). How do digital capabilities affect firm performance? The mediating role of technological capabilities in the "new normal". *Journal of Innovation & Knowledge, 7*(2), 100171. https://doi.org/10.1016/j.jik.2022.100171

Hunjra, A. I., Zhao, S., Goodell, J. W., & Liu, X. (2024). Digital economy policy and corporate low-carbon innovation: Evidence from a quasi-natural experiment in China. *Finance Research Letters, 60*, 104910. https://doi.org/10.1016/j.frl.2023.104910

Huo, P., & Wang, L. (2022). Digital economy and business investment efficiency: Inhibiting or facilitating? *Research in International Business and Finance, 63*, 101797. https://doi.org/10.1016/j.ribaf.2022.101797

Jiang, Q., Li, J., Si, H., & Su, Y. (2022). The impact of the digital economy on agricultural green development: Evidence from China. *Agriculture, 12*(8), 1107. https://doi.org/10.3390/agriculture12081107

Kirschning, R., & Mrożewski, M. (2024). Revisiting the knowledge spillover paradox: The impact of infrastructure. *Small Business Economics, 63*(1), 1–20. https://doi.org/10.1007/s11187-023-00833-8

Lee, C. C., Tang, M., & Lee, C. C. (2023). Reaping digital dividends: Digital inclusive finance and high-quality development of enterprises in China. *Telecommunications Policy, 47*(2), 102484. https://doi.org/10.1016/j.telpol.2022.102484

Lee, C. C., & Wang, F. (2022). How does digital inclusive finance affect carbon intensity? *Economic Analysis and Policy, 75*, 174–190. https://doi.org/10.1016/j.eap.2022.05.010

Li, J., Chen, L., Chen, Y., & He, J. (2022). Digital economy, technological innovation, and green economic efficiency: Empirical evidence from 277 cities in China. *Managerial and Decision Economics, 43*(3), 616–629. https://doi.org/10.1002/mde.3406

Li, F., Zang, D., Chandio, A. A., Yang, D., & Jiang, Y. (2023). Farmers' adoption of digital technology and agricultural entrepreneurial willingness: Evidence from China. *Technology in Society, 73*, 102253. https://doi.org/10.1016/j.techsoc.2023.102253

Liu, Y., Zang, Y., & Yang, Y. (2020). China's rural revitalization and development: Theory, technology and management. *Journal of Geographical Sciences, 30*, 1923–1942. https://doi.org/10.1007/s11442-020-1819-3

Ma, D., & Zhu, Q. (2022). Innovation in emerging economies: Research on the digital economy driving high-quality green development. *Journal of Business Research, 145*, 801–813. https://doi.org/10.1016/j.jbusres.2022.03.041

Pan, W., Xie, T., Wang, Z., & Ma, L. (2022). Digital economy: An innovation driver for total factor productivity. *Journal of Business Research, 139*, 303–311. https://doi.org/10.1016/j.jbusres.2021.09.061

Park, R. E. (1932). The development of extraterritoriality in China. *American Journal of Sociology, 37*(5), 806–809. https://doi.org/10.1086/215869

Partridge, M. D., Boarnet, M., Brakman, S., & Ottaviano, G. (2012). Introduction: Whither spatial econometrics? *Journal of Regional Science, 52*(2), 167–171. https://doi.org/10.1111/j.1467-9787.2012.00767.x

Peng, Z., & Dan, T. (2023). Digital dividend or digital divide? Digital economy and urban–rural income inequality in China. *Telecommunications Policy, 47*(9), 102616. https://doi.org/10.1016/j.telpol.2023.102616

Peng, Y., & Tao, C. (2022). Can digital transformation promote enterprise performance? From the perspective of public policy and innovation. *Journal of Innovation & Knowledge, 7*(3), 100198. https://doi.org/10.1016/j.jik.2022.100198

Rijswijk, K., Klerkx, L., Bacco, M., Bartolini, F., Bulten, E., Debruyne, L., Dessein, J., Scotti, I., & Brunori, G. (2021). Digital transformation of agriculture and rural areas: A socio-cyber-physical system framework to support responsibilisation. *Journal of Rural Studies, 85*, 79–90. https://doi.org/10.1016/j.jrurstud.2021.05.003

Shahbaz, M., Patel, N., Du, A. M., & Ahmad, S. (2024). From black to green: Quantifying the impact of economic growth, resource management, and green technologies on CO_2 emissions. *Journal of Environmental Management, 360*, 121091. https://doi.org/10.1016/j.jenvman.2024.121091

Shen, Z., Wang, S., Boussemart, J. P., & Hao, Y. (2022). Digital transition and green growth in Chinese agriculture. *Technological Forecasting and Social Change, 181*, 121742. https://doi.org/10.1016/j.techfore.2022.121742

Struik, P. C., & Kuyper, T. W. (2017). Sustainable intensification in agriculture: The richer shade of green. *Agronomy for Sustainable Development, 37*(5), 1–15. https://doi.org/10.1007/s13593-017-0445-7

Sun, H., Edziah, B. K., Kporsu, A. K., Sarkodie, S. A., & Taghizadeh-Hesary, F. (2021). Energy efficiency: The role of technological innovation and knowledge spillover. *Technological Forecasting and Social Change, 167*, 120659. https://doi.org/10.1016/j.techfore.2021.120659

Tan, L., Yang, Z., Irfan, M., Ding, C. J., Hu, M., & Hu, J. (2024). Toward low-carbon sustainable development: Exploring the impact of digital economy development and industrial restructuring. *Business Strategy and the Environment, 33*(3), 2159–2172. https://doi.org/10.1002/bse.3584

Tang, Y., & Chen, M. (2022). The impact of agricultural digitization on the high-quality development of agriculture: An empirical test based on provincial panel data. *Land, 11*(12), 2152. https://doi.org/10.3390/land11122152

Tapscott, D. (1996). *The digital economy: Promise and peril in the age of networked intelligence*. McGraw-Hill.

Wang, H., Li, G., & Hu, Y. (2024a). Impact of the digital economy on public security: Evidence from rural China. *Applied Economics Letters, 31*, 1–5. https://doi.org/10.1080/13504851.2024.2331665

Wang, H., Peng, G., & Du, H. (2024b). Digital economy development boosts urban resilience: Evidence from China. *Scientific Reports, 14*(1), 2925. https://doi.org/10.1038/s41598-024-52191-4

Wang, S., Song, Y., Du, A. M., & Liang, J. (2024c). The digital economy and entrepreneurial dynamics: An empirical analysis of urban regions in China. *Research in International Business and Finance, 71*, 102459. https://doi.org/10.1016/j.ribaf.2024.102459

Wen, Z., Chang, L., Hau, K. T., & Liu, H. (2004). Testing and application of the mediating effects. *Acta Psychologica Sinica, 36*(5), 614–620.

Xu, J., Tong, X., & Yang, B. (2024). The spatial spillover effect of carbon emission trading scheme on green innovation in China's cities. *Annals of Regional Science*, 1–31. https://doi.org/10.1007/s00168-024-01285-y

Xu, N., Zhao, D., Zhang, W., Liu, M., & Zhang, H. (2022). Does digital transformation promote agricultural carbon productivity in China? *Land, 11*(11), 1966. https://doi.org/10.3390/land11111966

Yang, C., Ji, X., Cheng, C., Liao, S., Obuobi, B., & Zhang, Y. (2024). Digital economy empowers sustainable agriculture: Implications for farmers' adoption of ecological agricultural technologies. *Ecological Indicators, 159*, 111723. https://doi.org/10.1016/j.ecolind.2024.111723

Yang, G., Zhou, C., & Zhang, J. (2023). Does industry convergence between agriculture and related sectors alleviate rural poverty: Evidence from China. *Environment, Development and Sustainability, 25*(11), 12887–12914. https://doi.org/10.1007/s10668-022-02594-y

Yi, M., Liu, Y., Sheng, M. S., & Wen, L. (2022). Effects of digital economy on carbon emission reduction: New evidence from China. *Energy Policy, 171*, 113271. https://doi.org/10.1016/j.enpol.2022.113271

Yilmaz, S., Haynes, K. E., & Dinc, M. (2002). Geographic and network neighbors: Spillover effects of telecommunications infrastructure. *Journal of Regional Science, 42*(2), 339–360. https://doi.org/10.1111/1467-9787.00262

Zhang, Y. F., Ji, M. X., & Zheng, X. Z. (2023a). Digital economy, agricultural technology innovation, and agricultural green total factor productivity. *SAGE Open, 13*(3), 21582440231194388. https://doi.org/10.1177/21582440231194388

Zhang, Y., Ma, X., Pang, J., Xing, H., & Wang, J. (2023b). The impact of digital transformation of manufacturing on corporate performance: The mediating effect of business model innovation and the moderating effect of innovation capability. *Research in International Business and Finance, 64*, 101890. https://doi.org/10.1016/j.ribaf.2023.101890

Zhang, Z., Sun, C., & Wang, J. (2023c). How can the digital economy promote the integration of rural industries? Evidence from China. *Agriculture, 13*(10), 2023. https://doi.org/10.3390/agriculture13102023

Zhao, S., Teng, L., Arkorful, V. E., & Hu, H. (2023). Impacts of digital government on regional eco-innovation: Moderating role of dual environmental regulations. *Technological Forecasting and Social Change, 196*, 122842. https://doi.org/10.1016/j.techfore.2023.122842