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Research on the Role of Digital Economy in Promoting Rural Revitalization: A Study from the Perspective of Industrial Agglomeration

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Abstract: Rural revitalization is an essential pathway for socialist modernization and a crucial means of promoting common prosperity for all people. As a new form of productive force, the digital economy has become a key engine driving rural revitalization. This study adopts the theoretical framework of New Economic Geography and, from the perspective of industrial agglomeration, systematically explores the impact mechanism of the digital economy on rural revitalization at the theoretical level.

To further examine the impact of the digital economy on rural revitalization, this paper constructs a bidirectional panel fixed effects model, a mediation effect model, and a threshold regression estimation model for empirical testing. The research findings indicate that:

The digital economy has a significant positive impact on rural revitalization.

Industrial agglomeration plays a mediating role in the relationship between the digital economy and rural revitalization, where the digital economy promotes rural revitalization through industrial agglomeration.There exists a threshold effect of industrial agglomeration in the digital economy's promotion of rural revitalization. The continuous development of industrial agglomeration accelerates the positive effect of the digital economy on rural revitalization. Based on these findings, this paper proposes policy recommendations to foster rural digital talent, enhance the application of digital economy, and improve digital information platforms to promote rural industrial clustering, ultimately advancing comprehensive rural revitalization.

Keywords: Digital Economy; Industrial Agglomeration; Rural Revitalization
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1.Introduction

1.1 Research Background and Significance

1.1.1 Research Background

At present, China has achieved a comprehensive victory in poverty alleviation and successfully embarked on a new journey of socialist development. However, the "three rural" issues (agriculture, rural areas, and farmers) remain a top priority for the entire party. In 2017, at the 19th National Congress of the Communist Party of China, General Secretary Xi Jinping first proposed the rural revitalization strategy, elevating the priority development of agriculture and rural areas to the level of a national strategy. The 20th National Congress of the Communist Party of China emphasized the need to comprehensively

promote rural revitalization and build a modern socialist country in all respects. The No. 1 Central Document of 2023 further outlined the need to adhere to the priority development of agriculture and rural areas, promote urban-rural integration, and advance key tasks such as rural development, rural construction, and rural governance to fully implement rural revitalization. The No. 1 Central Document of 2024 once again stated that to advance Chinese-style modernization, it is essential to consolidate the foundation of agriculture and promote comprehensive rural revitalization as the overarching task of "three rural" work in the new era and new journey. Accelerating the modernization of agriculture and rural areas serves as a solid foundation for building a modern socialist country. Given this national strategic orientation, there is an urgent need for research on effectively addressing the "three rural" issues in the new era and promoting comprehensive rural revitalization.

Industrial prosperity is a crucial aspect of rural revitalization, and fostering advantageous industrial clusters can help shape a new pattern for this initiative. The "National Rural Industrial Development Plan (2020-2025)" highlights that developing rural industries is a fundamental pillar of comprehensive rural revitalization, an important support for consolidating and enhancing a well-off society, and a key driver for advancing agricultural and rural modernization. The process of industrial clustering leverages unique natural environmental resources to create distinctive competitive advantages (Bai Xiaozhong & He Yan, 2012), thereby enhancing industrial competitiveness (Zhou Haichuan et al., 2023) and providing momentum for comprehensive rural revitalization. Particularly with the rapid development and application of internet technology, the digital economy has become one of the major driving forces of China's economic growth. The informatization of rural areas and the application of digital technology are increasingly integrated into industrial development, facilitating the aggregation of advantageous industries and becoming a critical factor influencing rural revitalization. The report of the 20th National Congress of the Communist Party of China proposed accelerating the development of the digital economy, promoting deep integration between the digital economy and the real economy, and creating globally competitive digital industry clusters. Digitalization can drive the healthy development of platform and shared economies, thereby upgrading industrial value chains and empowering the process of industrial clustering. Consequently, advancing industrial clustering to achieve comprehensive rural revitalization necessitates exploring the deep integration and application of the digital economy in rural industrial development—this serves as both the logical starting point of this research and a significant developmental opportunity.

1.1.2 Research Significance

At the theoretical level, this project is based on the theory of new economic geography and analyzes the intrinsic mechanisms through which the digital economy facilitates rural revitalization from the perspective of industrial clustering. This provides theoretical support for understanding the micro-level impact of the digital economy on rural revitalization.

At the practical level, this project promotes industrial clustering development through three key aspects: enhancing information exchange via the digital economy, driving industrial upgrading, and integrating the entire industrial chain. From this perspective, it provides theoretical support and practical guidance for government departments in formulating rural revitalization strategies and digital economy development plans.

1.2 Research Plan

1.2.1 Research Objectives

Constructing a Theoretical Analytical Framework for the Digital Economy's Role in Rural Revitalization. Based on the theory of New Economic Geography, this study delves into the impact mechanism of the digital economy in promoting rural revitalization. From the perspective of industrial agglomeration, it clarifies the role of the digital economy in rural revitalization and establishes a theoretical logical framework for how the digital economy facilitates rural revitalization.

Developing an Empirical Model for the Digital Economy's Role in Rural Revitalization. By integrating theoretical analysis with statistical data, this study employs a bidirectional fixed-effects panel regression model, a mediation effect model, and a threshold regression model to empirically examine the impact of the digital economy on rural revitalization through the scale effect of industrial agglomeration. This results in the formation of an empirical model for testing the role of the digital economy in rural revitalization.

Innovating Policy Support for the Digital Economy's Role in Rural Revitalization. Based on the findings from research objectives (1) and (2), this study constructs a theoretical system for the digital economy's role in rural revitalization. It

proposes innovative policy recommendations, including continuously cultivating digital talent in rural areas, fostering digital industry clusters, and improving digital information platforms. These measures aim to drive agricultural industrial agglomeration and comprehensively advance rural revitalization.

1.2.2 Technical Roadmap

This study integrates New Economic Geography theory to construct an index system for digital economy development and rural revitalization. Using industrial agglomeration as an intermediary variable, it collects panel data from 31 provinces in China from 2011 to 2022 and employs a bidirectional fixed-effects panel model and a mediation effect model to measure both the direct effect of the digital economy on rural revitalization and the indirect effect through industrial agglomeration. Furthermore, a threshold regression estimation model is constructed to determine whether there is a threshold effect between the digital economy and rural revitalization. Based on the empirical analysis results, targeted policy innovations for digital economy empowerment in rural revitalization are proposed.

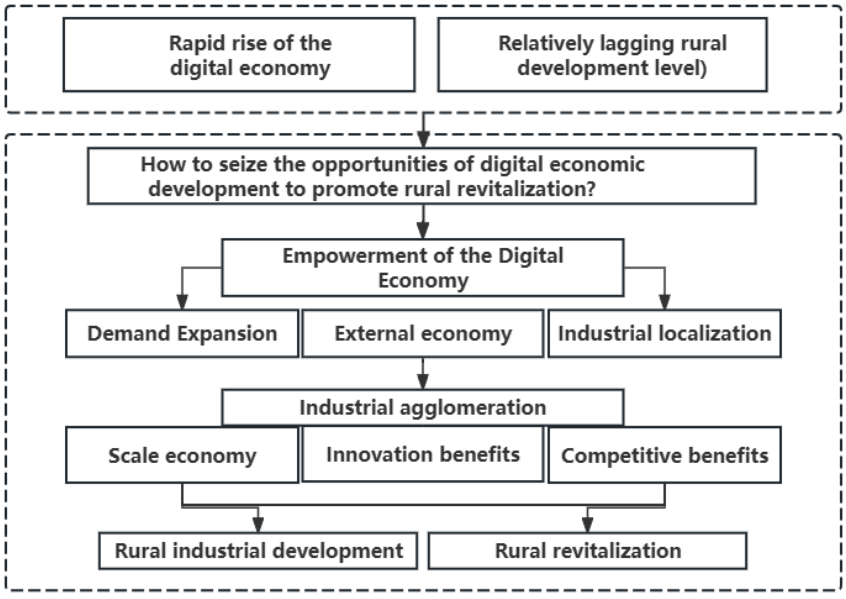
Compared with existing research, this study presents three key innovations:

First, based on previous studies, this research integrates New Economic Geography theory to systematically examine both the direct and indirect effects of the digital economy on rural revitalization from a theoretical perspective. New Economic Geography theory emphasizes the significance of spatial economic structures and industrial agglomeration. Within this theoretical framework, this study explores how the digital economy promotes industrial agglomeration and, in turn, empowers rural revitalization. By constructing an analytical framework that considers the geographical distribution of economic activities, it delves deeper into the interactions between the digital economy and industrial agglomeration and their impact on rural revitalization.

Second, this study examines the role of industrial agglomeration as a channel through which the digital economy facilitates rural revitalization, further exploring the synergistic mechanism between the digital economy and industrial agglomeration. This includes analyzing the application of digital technologies in industrial agglomeration and how industrial agglomeration fosters the development of the digital economy, thereby promoting rural revitalization. Research on this synergistic mechanism helps reveal the intrinsic relationship and mutual interactions between the digital economy and industrial agglomeration.

Third, this study provides new perspectives and methods for more precise rural revitalization policy formulation. By conducting an in-depth analysis of the coordinated development of the digital economy and industrial agglomeration, policymakers can more accurately identify the key bottlenecks and opportunities in rural revitalization. This enables the development of more effective policies and measures to enhance rural revitalization through targeted digital economy applications.

Figure 1 Technical Roadmap



2.Literature Review

2.1 Domestic and International Research Status

As China enters a new stage of socialist development, the "three rural" (agriculture, rural areas, and farmers) issues remain a top priority for the entire Party. The 2023 Central No. 1 Document, titled "Opinions of the CPC Central Committee and the State Council on Learning from the 'Thousand Villages Demonstration, Ten Thousand Villages Renovation' Project to Effectively Promote Comprehensive Rural Revitalization", is the 12th No. 1 document issued since the 18th National Congress of the Communist Party of China, highlighting the continuous central focus on rural development. The document emphasizes that advancing Chinese-style modernization requires a steadfast commitment to strengthening the agricultural foundation and comprehensively promoting rural revitalization. Accelerating agricultural and rural modernization is the solid foundation for building a modern socialist country in all aspects.

As the dominant economic form following agricultural and industrial economies, the digital economy has become a key driver in reorganizing rural resource elements and reshaping rural economic structures. At this critical period of digital economy development, the question of how to leverage the digital economy to drive rural revitalization remains a crucial issue for rural development.

2.1.1 Driving Mechanism of the Digital Economy in Promoting Rural Revitalization

With the continuous improvement and development of information technology, advancements in digital technology are driving the growth of rural areas. At present, the digital economy is increasingly integrated with rural industrial development, becoming a new engine and driving force for the rural revitalization strategy. This study primarily explores the driving mechanism of the digital economy in rural revitalization by analyzing how it fosters the development of new rural industries and business models, promotes industrial agglomeration, and ultimately drives comprehensive rural revitalization.

Leveraging its distinctive characteristics, the digital economy facilitates industrial agglomeration through three key aspects: enhancing information exchange, driving industrial upgrading, and integrating the entire industrial chain. From the perspective of information exchange, the digital economy's strong information-sharing capabilities help reduce information asymmetry in industrial development (Huang Yongchun et al., 2022). By utilizing intelligent platforms to collect and process information, the digital economy enhances search efficiency, reduces initial costs of industrial development, and improves the supply-demand matching of supply chains, value chains, and innovation chains (Wang Wei & Wei Kehui, 2024)[1], ultimately optimizing resource allocation efficiency (Bai Peiwen & Yu Li, 2021). Additionally, under the digital economy model, digital inclusive finance can effectively lower transaction costs and improve transaction efficiency, thereby strengthening industrial agglomeration (Li Xiaoyuan & Liu Yumeng, 2021).

From the perspective of industrial upgrading, the digital economy, as a core element of industrial transformation, fundamentally restructures various aspects of economic activities (Hou Jian & Liu Qing, 2022)[2]. By promoting digitalization, greening, and low-carbon transformation of rural agriculture, the digital economy generates a synergistic effect greater than the sum of individual contributions (Han Jian & Li Jiangyu, 2022), enabling the upgrading of traditional agriculture (He Leihua et al., 2022, pp.1-18) and providing new momentum for industrial agglomeration (Zhang Yongheng & Chen Mei, 2022)[3].

From the perspective of integrating the entire industrial chain, the digital economy enhances agricultural production through digital technology empowerment (Tian Ye et al., 2021), promotes the digital, networked, and intelligent transformation of rural industries, and enables horizontal and vertical industry linkages with positive feedback effects, spreading to other closely related sectors (Guo Chaoxian & Miao Yufei, 2023). This fosters the deep integration of the primary, secondary, and tertiary agricultural industries, driving efficient collaboration in rural characteristic industries (Jiang Xiaojun & Jin Jing, 2022)[4], and promoting the construction and development of industrial agglomeration (Wu Jingwei & Jiang Jing, 2021).

Industrial agglomeration stimulates related industries, attracting new investments and offering fresh development momentum for rural areas. It enhances farmers' income, fosters specialized rural industries, and accelerates technology diffusion, thereby promoting rural revitalization.

First, industrial agglomeration provides new income channels for farmers. As industry scales expand, improvements in

mechanization, technological efficiency, labor specialization, and market bargaining power due to agglomeration economies significantly enhance regional agricultural productivity and efficiency (Zhang Zhexi et al., 2018)[5], thereby increasing farmers' incomes. Additionally, industrial agglomeration helps enhance labor productivity and production efficiency (Li Jing, 2023), freeing up rural labor for other economic activities, diversifying income sources, and further supporting rural revitalization.

Second, industrial agglomeration fosters the development of specialized rural industries. Industrial agglomeration capitalizes on location advantages, bringing together a large number of related enterprises in a given area, thereby forming a sustained competitive advantage (Yang Xiuyun et al., 2021). Rural leading industries with unique characteristics and comparative advantages tend to cluster geographically, benefiting from agglomeration effects (Sun Hui, 2007). By deepening and expanding specialized rural industries and products, rural areas can strengthen their distinctive economic advantages (Guang Ya, 2018) and convert comparative resource advantages into competitive economic advantages (Yang Yadong et al., 2023)[6], thereby effectively advancing comprehensive rural revitalization.

Third, industrial agglomeration accelerates technology diffusion. In the process of industrial agglomeration, businesses must enhance their knowledge accumulation, knowledge flow, and knowledge absorption to improve both their internal capabilities and external contractual relationships (Meng Ziheng et al., 2022)[7], facilitating specialized technology learning. Additionally, increased economic interaction within industrial clusters accelerates information and technology dissemination (Liu Xuehua et al., 2018), leading to technology spillover effects (Zhang Aili & Zhang Xinyu, 2023), ultimately stimulating rural economic growth and promoting comprehensive rural revitalization.

2.1.2 Implementation Pathways of the Digital Economy in Promoting Rural Revitalization

In the new era, rural development has achieved some success under the impetus of the digital economy. However, there are still challenges such as weak digital technology infrastructure, low levels of digitalization and application, and a shortage of specialized talents in rural areas. Based on the driving mechanisms of the digital economy in promoting rural revitalization, this study explores the implementation pathways from the perspectives of integrating the digital economy into rural multi-stakeholders, establishing digital technology research and application platforms, and cultivating specialized digital technology talents to facilitate the process of digital economy-driven rural revitalization.

Integrating the digital economy into rural industrial development is the direct pathway through which the digital economy promotes rural revitalization. The digital economy can only serve as a new engine for industrial agglomeration when deeply integrated with rural enterprises. Local governments should accelerate the promotion of key digital agricultural technologies in agricultural production and enhance innovation and technical exchanges among enterprises (Song Changying et al., 2022), thereby reducing transaction and financing costs for businesses (Fang Fuqian et al., 2023). Meanwhile, the digitalization of knowledge, information, and human resources should be facilitated to enhance infrastructure digitalization, allowing digital technology to be better incorporated into rural enterprise production (Zhao Deqi & Ding Yiwen, 2021). This approach can inject new momentum into the transformation and upgrading of traditional industries (Liu Yang et al., 2020)[8].

Establishing digital technology research and application platforms is the fundamental pathway for the digital economy to promote rural revitalization. The application of digital technology depends on technological development from universities and agricultural research institutions, as well as promotion and implementation by government platforms. It is necessary to actively encourage collaboration between universities, research institutes, and agricultural enterprises to improve the efficiency of technology commercialization in agriculture and address challenges in digital agriculture development (Feng Chaorui & Xu Hongyu, 2021). Additionally, the government should leverage leading large-scale agricultural enterprises to guide the digitalization of industries, using rural digital leaders to drive industrial integration (Song Xuguang et al., 2022). For small and medium-sized enterprises (SMEs), targeted policies should be introduced to promote the agglomeration and development of rural SMEs (Liu Shuchun et al., 2021). Furthermore, enhancing digital awareness and skills among rural workers is crucial (Wang Ruifeng, 2022), which requires organizing specialized training programs on the digital economy (Ma Huanglong & Qu Xiao'e, 2022)[9].

Cultivating specialized digital technology talents is the effective pathway for the digital economy to drive rural revitalization.

Human capital serves as the internal driving force for the digital economy's role in rural revitalization (He Leihua et al., 2022, pp.1-18). The rapid advancement of the digital economy places higher demands on the workforce (Liu Xiaoming, 2023) [10]. To ensure sustainable rural development, it is essential to continuously expand the pool of digital talents in rural areas, thereby enhancing the vitality of rural industrial development (Zhang Yunping & Luan Jing, 2022). The government should establish and improve a digital training system for rural residents, selecting a group of digitally capable and willing rural residents to participate in vocational digital skills training, providing high-quality labor for industrial agglomeration (Wang Haixia et al., 2023)[11]. Additionally, it is crucial to cultivate a new generation of farmers who are proficient in networking, passionate about agriculture, and skilled in business operations, thereby fostering new rural business entities and stimulating the intrinsic driving force of rural industrial development (Zhang Wang & Bai Yongxiu, 2022).

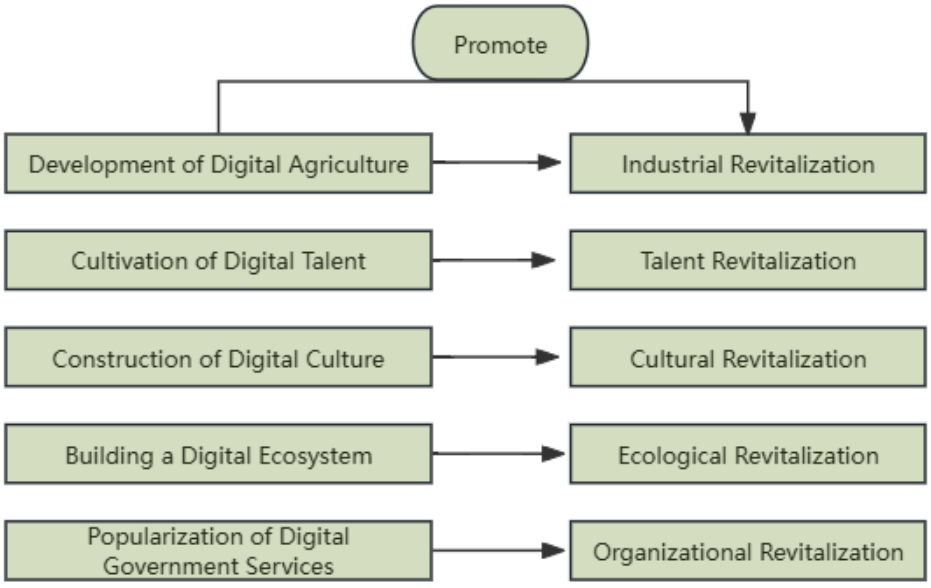
3.Theoretical Mechanism of the Digital Economy in Promoting Rural Revitalization

3.1 Direct Impact of the Digital Economy on Rural Revitalization

This study, based on the "Five Revitalizations" strategy of rural revitalization, explores the direct impact of the digital economy in empowering industrial, talent, cultural, ecological, and organizational revitalization[12]. The focus is on how the digital economy facilitates rural industrial revitalization.

The digital economy promotes rural industrial revitalization by advancing digital agriculture. With the continuous integration of big data, cloud computing, and other digital technologies into agriculture, the modernization and smart development of agriculture have significantly improved, effectively enhancing agricultural production efficiency. Supported by digital technology, the emergence of digital e-commerce and digital logistics platforms has extended agricultural industry chains and increased the added value of agricultural products. Under the empowerment of digital technologies, new agricultural management systems are rapidly forming, accelerating the transformation of rural business entities toward family farms, farmer cooperatives, and leading enterprises, thereby improving agricultural industry operational efficiency. The development of rural industries directly creates diverse and extensive employment opportunities for local farmers, effectively narrowing the urban-rural income gap and advancing the realization of rural revitalization.

Figure 2 Pathways Through Which the Digital Economy Directly Influences Rural Revitalization



The digital economy drives rural talent revitalization through digital talent cultivation. The digital transformation of agriculture and rural areas cannot be achieved without the support of digital talent. Against the backdrop of the integration of the digital economy and the real economy, efforts to cultivate digital economy talent have been significantly enhanced. The mechanism for attracting rural digital talent has continuously improved, promoting the enhancement of farmers' digital skills and literacy. This enables farmers to effectively use modern agricultural production technologies and information infrastructure, thereby boosting the overall efficiency and modernization of rural production activities.

The digital economy facilitates rural cultural revitalization by promoting digital cultural development. As the digital economy

integrates with rural culture, digital technologies are increasingly applied to rural landscapes, folk activities, and other cultural settings. This not only stimulates rural tourism development but also creates new opportunities for rural cultural dissemination. By leveraging new media and digital platforms, the digital economy enhances villagers' participation in cultural activities, improves the overall ideological and cultural level of farmers, and advances the construction of rural spiritual civilization.

The digital economy promotes rural ecological revitalization by fostering a digital ecological environment. Within the broader context of digital technology empowering rural revitalization, the application of digital water management, soil improvement technologies, and other innovations has significantly enhanced water quality and soil conditions in rural areas, contributing to the restoration of rural ecosystems. The establishment of digital air quality forecasting systems and automated water quality monitoring systems provides efficient support for environmental management, enabling dynamic monitoring and scientific early warning of rural ecological conditions. These systems facilitate regional ecological data sharing, thereby enhancing rural ecological governance and development.

The digital economy drives rural organizational revitalization through the promotion of digital governance. The development of digital governance has transcended traditional rural governance models. By utilizing big data, artificial intelligence, and other digital technologies, digital governance platforms can accurately assess the real needs of rural residents, optimize public service systems, and improve the overall welfare of rural communities. The widespread adoption and application of the internet and modern communication technologies eliminate physical space constraints, empowering rural grassroots self-governance. By integrating online and offline decision-making models, villagers can actively participate in rural governance, thereby enhancing the vitality of community self-governance.

The digital economy has had a positive impact on all five aspects of rural revitalization—industrial revitalization, talent revitalization, cultural revitalization, ecological revitalization, and organizational revitalization. Based on this, the study proposes the following hypothesis:

H1: The digital economy has a direct and positive impact on rural revitalization.

3.2 Impact of Digital Economy-Enabled Rural Industrial Agglomeration on Rural Revitalization

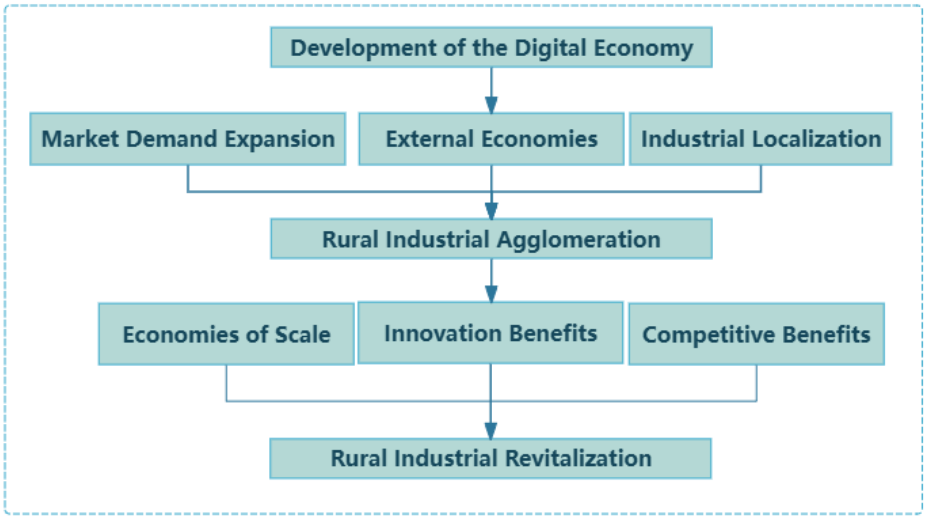
This study analyzes the theoretical mechanism of how the digital economy enables rural industrial agglomeration to drive rural revitalization, which is divided into two parts. First, based on New Economic Geography theory, this study explores the theoretical mechanism of the digital economy in facilitating rural industrial agglomeration. Second, by combining the agglomeration effects of industrial clusters with rural industrial development, this study examines how rural industrial agglomeration promotes rural industrial revitalization, ultimately leading to comprehensive rural revitalization.

New Economic Geography theory states that demand factors, external economies, and industrial localization are the three key conditions for forming industrial agglomeration. The digital economy, characterized by inclusiveness, innovation, and strong penetration, plays an active role in these three conditions, thereby promoting rural industrial agglomeration. First, in terms of demand factors, in regions with strong demand, transaction costs between suppliers and buyers are relatively low, and convenient transportation conditions make it easier to generate increasing returns to scale. The popularization of rural internet has broken the urban-rural information barrier, reducing transaction costs between supply and demand and expanding the market for rural products. The application of Internet of Things (IoT) technology has optimized urban-rural logistics efficiency, lowered logistics costs, and enhanced the market competitiveness of rural products, thereby increasing product demand. Second, New Economic Geography theory categorizes external economies into labor market pooling, specialized intermediate products and services, and technological spillovers. The digital economy promotes these aspects in multiple ways. The emergence of digitalized multi-employment and labor security service platforms has mitigated structural and frictional mismatches in the labor market, allowing rural industries to attract and accumulate more technical talent, thereby playing the "reservoir effect" in the labor market. The development of digital logistics, inclusive finance, and digital cultural industries provides specialized intermediate products and services, enhancing the innovation capacity and industrial competitiveness of rural industries. The network externality and spillover effects of digital technology and its applications further contribute to the formation of rural industrial clusters. Finally, as the national rural industry development plans, such

as “One Village, One Product”, “One Town, One Specialty”, and “One County, One Industry”, are continuously implemented, the localization trend of rural industries is strengthening. The establishment of digital and modern agricultural industrial parks has created favorable conditions for rural industrial agglomeration.

The digital economy, as a new economic paradigm, has played a positive role in fostering rural industrial agglomeration, further driving the development and revitalization of rural industries.

Figure 3 Pathways Through Which the Digital Economy Achieves Rural Industrial Revitalization via Rural Industrial Agglomeration



Rural industrial agglomeration fosters an integrated and synergistic rural industrial development model by leveraging external economies of scale, innovation benefits, and competitive advantages, thereby promoting rural revitalization through industrial revitalization.

First, the continuous concentration of rural enterprises leads to external economies of scale, facilitating internal division of labor and cooperation within rural industries. External economies of scale reduce raw material search and transaction costs for upstream and downstream enterprises in production, refine industrial chain specialization, enhance labor productivity, and enable more efficient use of rural infrastructure, providing necessary supporting products and services for production. In terms of product sales, industrial clusters improve bargaining power, attract increased government investment in public services and infrastructure, and enhance rural industrial productivity.

Second, rural industrial agglomeration drives innovation by increasing personnel mobility and communication among rural enterprises, fostering innovative thinking among employees, and accelerating the generation of new ideas. Moreover, the clustering of rural enterprises facilitates knowledge and technology spillovers, expediting the dissemination of new agricultural production technologies and processes, thereby enhancing rural industrial technological innovation and application capabilities.

Finally, rural industrial agglomeration intensifies competition, compelling rural enterprises to continuously reduce costs, adopt advanced agricultural production technologies, improve product quality, and enhance both production efficiency and competitiveness. By stimulating rural industrial growth, industrial agglomeration plays a crucial role in driving rural revitalization.

However, the digital divide may exist in regions with varying levels of digital economic development. In digitally advanced areas, rural industries benefit from widespread adoption of digital technology, higher levels of farmer digital literacy, and greater contributions of industrial agglomeration to rural revitalization. In contrast, digitally underdeveloped regions face a more pronounced digital divide, preventing some farmers from participating in the digital economy and hindering the adoption of digital technologies in rural industries, thereby limiting the impact of industrial agglomeration on rural revitalization.

Based on this, the following hypotheses are proposed:

H2: The digital economy influences rural revitalization by affecting industrial agglomeration.

H3: Industrial agglomeration has a nonlinear impact on rural revitalization.

4.Empirical Test of the Digital Economy in Promoting Rural Revitalization

4.1 Model Construction

4.1.1 Bidirectional Fixed-Effects Panel Model

To examine the impact of the digital economy on rural revitalization, a bidirectional fixed-effects model is established to verify the direct impact relationship. The model is specified as follows:

$$Re\_rural_{it} = \alpha_0 + \alpha_1 Dig_{it} + X_{it} + \varepsilon_{it} \quad (1)$$

represents the rural revitalization score of province iii in year ttt，denotes the level of digital economy development of province iii in year ttt.，represents a series of control variables affecting rural revitalization.，is the random error term.

4.1.2 Mediation Effect Model

Based on the verification of the coefficient α1\alpha_1α1 in equation (1), which measures the impact of the digital economy on rural revitalization, and following the theoretical analytical framework, a three-stage mediation effect model is constructed to examine the mediating role of industrial agglomeration in the relationship between the digital economy and rural revitalization. The model is specified as follows:

$$Industrial_{it} = \beta_0 + \beta_1 Dig_{it} + \beta_{it} X_{it} + \varepsilon_{it} \quad (2)$$

$$Re\_rural_{it} = \gamma_0 + \gamma_1 Dig_{it} + \gamma_2 Industrial_{it} + \gamma_{it} X_{it} + \varepsilon_{it} \quad (3)$$

4.1.3 Panel Threshold Model

To empirically examine the threshold effect of industrial structure in the relationship between the digital economy and rural revitalization, the panel threshold model is constructed as follows:

$$Re\_rural_{it} = \lambda_0 + \lambda_1 Dig_{it} + I(Industrial_{it} \le \theta) + \lambda_2 Dig_{it} + I(Industrial_{it} > \theta) + \lambda_{it} X_{it} + \varepsilon_{it} \quad (4)$$

In equation (4), represents the threshold value, and is an indicator function that takes the value 1 when the condition inside is met and 0 otherwise.

4.2 Variable Selection

4.2.1 Dependent Variable: Rural Revitalization Index (Re_rural)

The dependent variable is rural revitalization. There is no universally accepted measurement standard in academic research. Based on the requirements of the 19th National Congress of the Communist Party of China on rural revitalization, this study draws on existing research indicators (Zhang Ting et al., 2018)[13] and constructs a rural revitalization index system from five dimensions: industrial prosperity, ecological livability, cultural flourishing, effective governance, and affluent living standards. The specific indicators are shown in Table 1. To avoid multicollinearity issues, this variable is log-transformed and denoted as lnY.

Table 1 Comprehensive Index of Rural Revitalization

Primary Indicator	Secondary Indicator	Attribute	Weight
Industrial Prosperity	Per Capita Primary Industry Output Value	+	0.065007
	Grain Production	+	0.2097
	ln Total Agricultural Machinery Power	+	0.047427
	ln Effective Irrigation Area	+	0.063023
Ecological Livability	Forest Coverage Rate	+	0.112117
	Household Garbage Harmless Disposal Rate	+	0.018068
	ln Number of Public Toilets	+	0.014573
	Number of Rural Doctors and Health Workers	+	0.133027
	ln Comprehensive Water Supply Production Capacity	+	0.030978
Cultural Flourishing	ln Local Government Education Expenditure	+	0.009785
	Literate Population / Number of People Aged 15 and Above	-	0.013345
	TV Program Coverage Rate	+	0.017411

Primary Indicator	Secondary Indicator	Attribute	Weight
Effective Governance	Per Capita Disposable Income of Rural Residents / Per Capita Disposable Income of Urban Residents	+	0.058891
	Per Capita Consumption Expenditure of Rural Residents / Per Capita Consumption Expenditure of Urban Residents	+	0.038297
	ln Rural Population	+	0.089632
Affluent Living Standards	ln Per Capita Disposable Income of Rural Residents	+	0.045286
	ln Per Capita Food, Tobacco, and Alcohol Consumption Expenditure of Rural Residents	+	0.031298
	ln Number of Rural Employment	+	0.05128

4.2.2 Core Independent Variable

Digital Economy Development Level (Dig). There is no universally accepted framework in academia for constructing digital economy indicators. This study draws on existing research (Yang Chengjia & Li Zhongxiang, 2023)[14] and establishes a digital economy development index system based on four dimensions: digital infrastructure, digital industrialization, industrial digitalization, and digital inclusive finance. The entropy method is used to measure the digital economy development level across different provinces in China, with the specific indicators detailed in Table 2. To mitigate multicollinearity issues, the variable is log-transformed and denoted as lnX.

Table 2 Comprehensive Index of Digital Economy

Primary Indicator	Secondary Indicator	Attribute	Weight
Digital Infrastructure	Internet Penetration Rate	+	0.06636
	Mobile Phone Penetration Rate	+	0.043356
	Optical Cable Line Length		0.102002333
Digital Industrialization	Total Telecom Business Volume	+	0.085871
	Number of Urban Employees in Information Transmission, Software, and IT Services	+	0.111873
	Software Business Revenue	+	0.121085
	Scale of Information Technology Service Revenue	+	0.10673
Industrial Digitalization	Proportion of Employees in Computer Services and Software Industry	+	0.057957
	Rural Electricity Consumption	+	0.143237
	E-commerce Sales Revenue	+	0.107292914
Digital Inclusive Finance	Digital Inclusive Finance Index	+	0.054235

4.2.3 Mediating Variable / Threshold Variable: Industrial Agglomeration Index (Ind-a)

Industrial agglomeration refers to the process of industries concentrating in specific regions, reflecting the spatial concentration characteristics of production resources. Based on the research context of this study, location entropy is used to measure industrial agglomeration. It is calculated as the ratio of the share of employment in the primary industry of a specific region to the national total primary industry employment, divided by the share of total employment in that region to the national total employment.

4.2.4 Control Variables

Considering the impact of fiscal expenditure, economic level, and fixed investment on rural revitalization, this study includes the following control variables:

Fiscal Support for Agriculture (Fis): Measured by the proportion of government expenditure on agriculture, forestry, and water affairs to total fiscal expenditure.

Economic Development Level (Dev): Measured by the natural logarithm of per capita GDP in each province.

Fixed Asset Investment (Fai): Measured by the fixed asset investment amount in each province.

4.3 Data Sources

Table 3 Descriptive Statistics of Variables

Variable	Variable Description	Sample Size	Mean	Standard Deviation	Min Value	Max Value
lnY	Log of Rural Revitalization Development Level	372	-0.897	0.287	-1.567	-0.570
lnX	Log of Digital Economy Development Level	372	-1.993	0.640	-3.201	-0.884
Fis	Fiscal Support for Agriculture	372	0.115	0.034	0.004	0.204
Dev	Economic Development Level	372	10.856	0.462	9.682	12.156
Fai	Fixed Asset Investment	372	19193.25	14846.34	516.31	65087.93
Ind-a	Industrial Agglomeration Index	372	0.259	0.507	4.42e-10	3.063

This study selects panel data from 31 provinces in China from 2011 to 2022 for empirical analysis. The data are sourced from the China Statistical Yearbook, provincial and municipal statistical yearbooks, and local statistical bureaus. Additionally, to ensure data completeness, scientific accuracy, and practical applicability, interpolation methods were used to fill in a small number of missing values. The descriptive statistics of each variable are shown in Table 3.

4.4 Empirical Results Analysis

4.4.1 Baseline Regression Results Analysis

According to the Hausman test, this study adopts a fixed-effects model for empirical analysis, and the results are shown in Table 4. From the table, it can be observed that the digital economy has a positive promoting effect on rural revitalization. Therefore, Hypothesis H1 is confirmed.

Table 4 Baseline Regression Results

	(1)	(2)	(3)	(4)
LNX	0.110*** (8.76)	0.105*** (8.13)	0.0911*** (6.67)	0.0816*** (6.50)
Fis		0.225*** (2.67)	0.289*** (3.79)	-0.102*** (-2.64)
Dev			0.103** (2.92)	0.192*** (5.62)
Fai				-0.00000283*** (-8.05)
Constant	-1.027*** (-38.71)	-1.050*** (-33.38)	-2.251*** (-5.46)	-3.252*** (-8.20)
R^2	0.99	0.99	0.99	0.99

* p<0.05, ** p<0.01, *** p<0.001

4.4.2 Mediation Effect Model

To verify the existence of an indirect effect mechanism between the digital economy and rural revitalization, this study selects industrial agglomeration level as a mediating variable for empirical analysis. The regression results are shown in Table 5.

As indicated in Table 5, the total effect of the digital economy on rural revitalization is 0.418, while the direct effect is 0.0932. Since the direct effect is smaller than the total effect, the mediation effect is present.

Thus, industrial agglomeration plays a mediating role in the process of the digital economy promoting rural revitalization, confirming Hypothesis H2.

Table 5 Mediation Effect Regression Results

	(1)	(2)
industrial		0.0277** (3.19)
lnx	0.418*** (5.30)	0.0932*** (7.23)
Fis	2.870** (2.86)	-0.181 (-1.14)
fai	0.0000103*** (4.67)	-0.00000311*** (-8.70)
dev	-0.275*** (-3.78)	0.199*** (5.91)
Constant	2.23*** (2.89)	-3.314*** (-8.46)
R^2	0.87	0.99
Total Effect	0.418	
Direct Effect	0.0932	
Indirect Effect	0.3248	

* p<0.05, ** p<0.01, *** p<0.001

4.4.3 Threshold Effect Test and Threshold Value Determination

Before conducting the threshold regression test, it is necessary to verify whether a threshold effect exists. If a threshold effect is detected, the number of thresholds and their values are further calculated. The test results are shown in Table 6. Based on the results, a single-threshold regression model is selected.

Table 6 Threshold Test Results

Threshold Type	F Statistic	10% Critical Value	5% Critical Value	1% Critical Value
Single	38.47*	25.5602	31.03	44.60
Double	16.24	21.6613	25.76	36.03

* p<0.05, ** p<0.01, *** p<0.001

The regression results of the threshold model are shown in Table 7. It can be observed that the threshold value is 0.1071. When the threshold value is not exceeded, the coefficient is 0.0998 and statistically significant. However, after surpassing the single threshold value, the coefficient increases, indicating that the positive impact of the digital economy on rural revitalization becomes more significant. This result suggests that the effect of the digital economy on rural revitalization through industrial structure is not continuous, thereby confirming Hypothesis H3.

Table 7 Threshold Effect Regression Estimation Results

Lny(Inda≤0.1071)	0.0998
Lny(Inda>0.1071)	0.1182
Control Variables	Control Variables
Constant	-3.171***(-5.76)

4.5 Empirical Conclusions

This study utilizes panel data from 31 provinces in China from 2011 to 2022. Based on the construction of rural revitalization and digital economy indicator systems, the entropy method is employed for measurement. Additionally, the bidirectional fixed-effects baseline regression model, mediation effect model, and threshold regression model are used to analyze the impact of the digital economy on promoting rural revitalization.

The empirical results show that: first, the digital economy has a significant positive impact on rural revitalization; second,

industrial agglomeration plays a mediating role in the relationship between the digital economy and rural revitalization, demonstrating that the digital economy can promote rural revitalization through industrial agglomeration; third, there is a threshold effect in the process of the digital economy promoting rural revitalization through industrial agglomeration. The continued development of industrial agglomeration can further accelerate the role of the digital economy in promoting rural revitalization.

5.Policy Recommendations

To fully leverage the digital economy in promoting rural revitalization and address the bottlenecks in rural industrial development, government policies should be further improved to support comprehensive rural revitalization. Based on the pathway in which the digital economy fosters industrial agglomeration and thereby drives rural revitalization, efforts should focus on facilitating rural industrial agglomeration to achieve comprehensive rural revitalization. Therefore, to develop the rural digital economy and enhance industrial agglomeration, policies should be strengthened in the following areas: continuous cultivation of rural digital talent, promotion of digital technology applications, and improvement of rural digital information platforms.

The first priority is to cultivate digital economy talent, which is an essential guarantee for achieving rural industrial agglomeration. Given the current shortage of digital economy professionals, the government should strengthen efforts to train rural digital talent and enhance farmers' digital literacy and skills. First, top-level planning, policy intervention, and coordinated collaboration should be enhanced, with targeted digital infrastructure development and intervention policies formulated to address existing rural development challenges. Second, the coverage of digital technology in rural areas should be expanded, utilizing administrative measures to facilitate the transmission of resources, expanding access to 5G, big data, and artificial intelligence, and lowering the barriers for farmers to engage with digital technology. Third, network-based training programs should be emphasized, providing farmers with practical opportunities in e-commerce live streaming, teaching them how to utilize new media tools, capture market information, and conduct digital marketing through mobile applications. Fourth, training content should be designed scientifically, helping farmers master smart agriculture software and digital tools, thereby improving their ability to apply digital solutions in agricultural production.

The second priority is to promote the agglomeration of rural specialty industries, which requires digital technology to drive the transformation and upgrading of agricultural industries. First, digital technology should be deeply integrated with traditional agriculture, enhancing the modularization of the agricultural industry system to form an interconnected, efficient, and secure industrial chain, achieving low-cost, high-quality, and fast logistics, and fostering new agricultural industries, business models, and markets. Second, modern technologies such as the internet, big data, and cloud computing should be leveraged for digital empowerment, upgrading agricultural production facilities to enhance intelligent, information-based, and modernized agricultural production, establishing an integrated information platform for production and sales, and promoting the development of "Internet + Agriculture." Third, technological upgrades should be prioritized in modern agricultural development, embedding digital technology into traditional production factors such as land, capital, and labor, expanding agricultural production scales appropriately to address market risks, while also utilizing digital technology to reshape traditional agricultural business models, thereby controlling uncertainties caused by large-scale production and ensuring the smooth transformation and upgrading of agricultural production.

The third priority is to maximize the increasing marginal benefits and external economies of the digital economy by improving rural digital information platforms to facilitate data circulation and sharing. First, technological and business model innovation should be encouraged. The government should provide funding support for research and development, promoting the adoption of new technologies such as artificial intelligence, the Internet of Things, and big data in rural digital information platforms to enhance their intelligence and automation, improving service efficiency. Additionally, rural digital platforms should be encouraged to explore new operational and service models, such as direct sales of agricultural products via social networks and digital promotion of rural tourism, to meet the evolving needs of rural development. Second, existing e-commerce platforms should be utilized to expand rural product sales channels. The government should facilitate close collaboration between e-commerce platforms and agricultural producers, promoting the upward mobility of agricultural

products in digital markets to increase farmers' incomes. Additionally, e-commerce regulations should be improved to combat online fraud, counterfeit products, and other violations, ensuring a sound legal environment for the healthy development of rural e-commerce platforms. Third, the functionality of rural e-government services should be enhanced, and data sharing should be strengthened. E-government service platforms should provide one-stop digital services, including online consultations, applications, and inquiries, making it easier for rural residents and enterprises to access public services. Furthermore, interdepartmental data sharing should be promoted to eliminate information silos and improve the efficiency and quality of e-government services.

By focusing on cultivating rural digital talent, promoting digital technology applications, and improving rural digital information platforms, policy measures can effectively empower the development of rural industrial clusters, thereby utilizing industrial agglomeration to drive comprehensive rural revitalization.

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Conflict of Interests

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