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The Influence Mechanism and Spatial Spillover Effect of Digital Economy on Urban-Rural Integrated Development: An Empirical Analysis based on Provincial Panel Data

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Abstract

The unbalanced urban-rural development remains a key bottleneck restricting China's realization of common prosperity, while the vigorous development of the digital economy provides new momentum for reshaping urban-rural relations. Based on panel data covering 30 provincial-level administrative regions in China from 2012 to 2025, this paper constructs a digital economy development index and a comprehensive index of urban-rural integrated development. Adopting the two-way fixed effects model, mediating effect model and Spatial Durbin Model, it systematically investigates the direct impact, transmission mechanism and spatial spillover effect of the digital economy on urban-rural integrated development. The results show that the digital economy exerts a significant positive direct effect on urban-rural integrated development (coefficient = 0.173, significant at the 1% level). Green innovation and optimized capital allocation act as two vital transmission channels, whose mediating effects account for 35.1% and 37.6% of the total effect respectively. Such promoting effect is more prominent in eastern regions, as well as regions with high infrastructure availability and abundant human capital. Furthermore, the digital economy generates significant positive spatial spillover effects, which account for 71.7% of the total effect. This research offers new theoretical perspectives and empirical evidence for understanding the evolution of urban-rural relations in the digital economy era.

Keywords

Digital Economy; Urban-Rural Integrated Development; Influence Mechanism; Spatial Spillover Effect.

1. Introduction

Unbalanced and inadequate urban-rural development is a core obstacle hindering China from achieving common prosperity and modernization goals. The urban-rural dual structure-where cities concentrate productive factors while rural areas lag behind-has long constrained rural endogenous impetus and development potential, and weakened the coordination and sustainability of the broader national economy. Promoting urban-rural integrated development and fostering a new type of worker-peasant and urban-rural relationship has become a major national strategic initiative in the new era. The Report to the 19th National Congress of the Communist Party of China first explicitly proposed to "establish and improve institutional mechanisms and policy systems for urban-rural integrated development", marking that urban-rural relations have entered a new phase of integrated development. The Report to the 20th National Congress of the CPC further clarified the significance of advancing urban-rural integration and coordinated regional development. The 2025 Central Economic Work Conference listed "coordinating the advancement of new-type urbanization and comprehensive rural revitalization to boost urban-rural integrated development" as a key task.

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This series of policy arrangements demonstrates that urban-rural integrated development is essential for advancing high-quality development and realizing common prosperity in the new era.

Meanwhile, driven by the rapid progress of a new generation of information technologies represented by big data, cloud computing and artificial intelligence, the digital economy has evolved into a pivotal force reorganizing global factor resources and restructuring the global economic system [1]. The Overall Layout Plan for Digital China Construction released in 2023 clearly sets out requirements to "strengthen, optimize and expand the digital economy" and "promote in-depth integration between digital technologies and the real economy" [2]. Can the digital economy function as a major driving force to break the urban-rural dual structure and accelerate urban-rural integration? Through what mechanisms does it exert influence? Does such impact feature regional heterogeneity and spatial spillover effects? These questions represent not only cutting-edge topics in academia, but also practical issues requiring urgent responses from policymakers [3].

Existing literature has carried out valuable explorations on the nexus between the digital economy and urban-rural integrated development, yet several limitations remain. In terms of research perspective, most studies focus on specific dimensions of urban-rural integration, lacking systematic examinations of its multi-dimensional characteristics [4]. Regarding mechanism analysis, most existing research merely conducts theoretical logical deduction without rigorous empirical verification of specific transmission paths [5]. From the spatial dimension, insufficient discussion has been devoted to the spatial spillover effect of the digital economy on urban-rural integrated development [6]. Against this backdrop, this paper constructs an evaluation indicator system for urban-rural integrated development covering economic, social, spatial and ecological dimensions. It empirically tests the internal transmission mechanism through two channels: green innovation and optimized capital allocation, and adopts the Spatial Durbin Model to identify spatial spillover effects.

2. Theoretical Mechanism

The direct influence of the digital economy on urban-rural integrated development can be interpreted from four dimensions:

Production and circulation. The digital economy strengthens urban-rural economic linkages by balancing production, distribution, exchange and consumption, raising productivity and improving information flow [7].

Factor mobility. It encourages free circulation and fair transactions of urban and rural resources, spurs enterprise investment, expands production scale, creates employment opportunities, and attracts returning talent.

Culture and ideology. Rising internet penetration accelerates the transmission of cutting-edge information, lifestyles and values from cities to rural areas. Meanwhile, rural customs and development conditions can be displayed more intuitively to urban residents, facilitating cultural exchanges between urban and rural regions [8].

Public services and spatial planning. Digital technologies such as big data and cloud computing optimize the allocation of public resources including education, healthcare, social security and elderly care, advancing equal access to public services for urban and rural residents. Additionally, the digital economy helps eliminate urban-rural dual thinking, weaken administrative boundary constraints, coordinate the spatial layout of urban and rural industries, ecology, residential areas and infrastructure, and lay the foundation for urban-rural spatial integration [9].

In terms of transmission mechanisms, this paper concentrates on two paths: green innovation and capital allocation optimization. Data serves as the core driving factor of the digital economy,

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which inherently bears green attributes consistent with the goals of low-carbon development, resource conservation and intelligent efficiency embedded in urban-rural integrated development. Digital technologies support enterprises' green transformation and guarantee low-carbon and stable operation of urban and rural economies [10]. At the same time, innovative models such as digital inclusive finance and big data credit investigation significantly lower the threshold and costs of financial services, improve capital allocation efficiency across regions and industries, and thereby advance urban-rural economic integration [11]. Moreover, endowed with cross-sector integration and deep penetration advantages, the digital economy can overcome geographical barriers, strengthen interregional division of labor and cooperation, and generate cross-regional spatial spillover effects [12].

Based on the above theoretical analysis, four research hypotheses are proposed:

H1: The digital economy facilitates urban-rural integrated development;

H2: The digital economy exerts positive impacts on urban-rural integrated development by promoting green innovation;

H3: The digital economy exerts positive impacts on urban-rural integrated development by optimizing capital allocation;

H4: The digital economy generates positive spatial spillover effects on urban-rural integrated development.

3. Research Design

This paper selects 30 provincial-level administrative regions in China (excluding Tibet, Hong Kong, Macao and Taiwan) from 2012 to 2025 as research samples. Data are mainly sourced from China Statistical Yearbook, China Information Yearbook, China Rural Statistical Yearbook, China Science and Technology Statistical Yearbook, the Peking University Digital Inclusive Finance Index [13], and the Green Patent Database of the National Intellectual Property Administration.

Table 1. Descriptive statistics of variables

Variables	Observations	Mean	Std	Min	Max
Urban-Rural Integrated Development Level (UR)	390	0.284	0.118	0.092	0.687
Digital Economy Development Level (DE)	390	0.236	0.152	0.041	0.724
Green Innovation Level (GI)	390	7.852	1.364	4.317	11.246
Capital Allocation Level (CA)	390	0.418	0.126	0.185	0.763
Economic Development Level (PGDP)	390	10.847	0.524	9.683	12.136
Government Intervention (GOV)	390	0.237	0.094	0.105	0.627
Opening-up Level (OPEN)	390	0.284	0.286	0.008	1.512
Human Capital Level (HUM)	390	0.021	0.006	0.008	0.043

For indicator system construction, this paper establishes a comprehensive evaluation system for urban-rural integrated development covering five dimensions: integration of economic development, factor flow, public services, infrastructure and ecological governance [14]. An evaluation system for the digital economy is built from four dimensions: digital infrastructure, digital industrialization, industrial digitalization and digital inclusive finance [15]. The entropy weight method is adopted for comprehensive measurement. In terms of model specification, the two-way fixed effects model is constructed to test the direct impact of the digital economy on urban-rural integration; the mediating effect model is used to examine the transmission channels of green innovation and capital allocation optimization; the Spatial Durbin Model is adopted to test spatial spillover effects [16].

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4. Empirical Results

4.1. Benchmark Regression Results

Benchmark regression results show that after gradually incorporating control variables as well as provincial and year two-way fixed effects, the coefficient of digital economy development level remains positive and significant at the 1% level.

Table 2. Benchmark Regression Results of Digital Economy on Urban-Rural Integrated Development

Variables	(1)	(2)	(3)	(4)
Digital Economy (DE)	0.284***	0.231***	0.206***	0.173***
(0.035)	(0.029)	(0.027)	(0.024)	
Economic Development Level (PGDP)	—	0.142***	0.118***	0.096***
—	(0.018)	(0.016)	(0.014)	
Government Intervention (GOV)	—	0.087**	0.064*	0.052*
—	(0.041)	(0.038)	(0.029)	
Opening-up Level (OPEN)	—	0.053**	0.041*	0.035
—	(0.026)	(0.023)	(0.022)	
Human Capital Level (HUM)	—	0.109***	0.087***	0.071***
—	(0.031)	(0.028)	(0.025)	
Province Fixed Effects	No	No	Yes	Yes
Year Fixed Effects	No	No	No	Yes
Observations	390	390	390	390
R^2	0.412	0.487	0.563	0.612

Note: ***, *, * denote statistical significance at the 1%, 5% and 10% levels respectively; robust standard errors are reported in parentheses.

According to Column (4) two-way fixed effects model results, each unit increase in the digital economy raises the level of urban-rural integrated development by approximately 0.173 units, which verifies Hypothesis H1. To address endogeneity bias caused by reverse causality and omitted variables, the instrumental variable approach is further applied. The interaction term between historical post office quantity and national internet users is selected as the instrumental variable [7]. The results indicate that after controlling for endogeneity, the coefficient of the digital economy equals 0.159 and remains significant at the 1% level, consistent with benchmark conclusions. In addition, a series of robustness tests, including alternative measurement of explanatory variables, exclusion of municipality samples, winsorization, adjusted sample intervals and alternative estimation methods, confirm that core conclusions remain substantially unchanged [15].

4.2. Mechanism Test Results

Estimation results of the mediating effect model reveal that the digital economy not only directly promotes urban-rural integrated development, but also generates indirect positive effects via two channels: advancing green technological innovation and optimizing the allocation of capital factors.

The mediating effect of green innovation accounts for 35.1% of the total effect (Sobel Z=4.37, significant at 1%); the mediating effect of capital allocation optimization accounts for 37.6% of the total effect (Sobel Z=4.12, significant at 1%) [17]. Both H2 and H3 are validated.

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Table 3. Regression Results of Mechanism Test

Variables	(1) GI	(2) UR	(3) CA	(4) UR
Digital Economy (DE)	0.204***	0.112***	0.196***	0.108***
(0.031)	(0.022)	(0.029)	(0.020)	
Green Innovation (GI)	—	0.298***	—	—
—	(0.041)	—	—	
Capital Allocation (CA)	—	—	—	0.332***
—	—	—	(0.045)	
Control Variables	Yes	Yes	Yes	Yes
Province / Year Fixed Effects	Yes	Yes	Yes	Yes
Observations	390	390	390	390
R^2	0.524	0.638	0.508	0.641

4.3. Heterogeneity Analysis Results

The promoting effect of the digital economy on urban-rural integration presents significant disparities across regions and development conditions.

Table 4. Regression Results of Heterogeneity Analysis

Grouping	Observations	Coefficient of Digital Economy	Intergroup Difference
Eastern Region	110	0.215***	—
Central Region	80	0.148***	—
Western Region	80	0.087	Significant
High-infrastructure Group	195	0.198***	—
Low-infrastructure Group	195	0.126***	Significant
High Human Capital Group	195	0.204***	—
Low Human Capital Group	195	0.119***	Significant

In terms of regional differences, the promoting effect is strongest in eastern regions (0.215), followed by central regions (0.148), while the effect is weakest and statistically insignificant in western regions (0.087) [18]. From the perspective of infrastructure level, the effect in regions with high infrastructure availability (0.198) is significantly larger than that in low-infrastructure regions (0.126). For human capital, the driving effect in high human capital regions (0.204) obviously exceeds that in low human capital regions (0.119) [1]. These findings demonstrate the existence of an "infrastructure threshold" and a "human capital threshold" in digital economy development.

4.4. Spatial Effect Analysis Results

Global Moran's I test confirms significant positive spatial autocorrelation in urban-rural integrated development, laying the foundation for applying spatial econometric models [19]. Regression results of the Spatial Durbin Model are shown below:

Table 5. Decomposition Results of Spatial Effects

Type of Effect	Inverse Distance Weight Matrix	Contiguity Weight Matrix
Direct Effect	0.163***	0.152***
(0.024)	(0.022)	
Indirect Effect (Spatial Spillover)	0.412***	0.374***
(0.048)	(0.043)	
Total Effect	0.575***	0.526***
(0.061)	(0.055)	

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Both the direct effect and spatial spillover effect of the digital economy are significantly positive. Under the inverse distance weight matrix, the direct effect is 0.163, the indirect effect is 0.412, and the total effect reaches 0.575; spatial spillover effects account for 71.7% of the total effect [20]. This indicates that local digital economic development not only boosts local urban-rural integration, but also significantly accelerates urban-rural integration in neighboring regions through demonstration effects, industrial linkages and technology spillovers, verifying Hypothesis H4.

5. Conclusion and Policy Implications

5.1. Research Conclusion

Based on panel data of 30 provincial-level administrative regions in China from 2012 to 2025, this paper systematically investigates the direct impact, transmission mechanism and spatial spillover effect of the digital economy on urban-rural integrated development. The major conclusions are as follows:

First, digital development consistently raises urban-rural integration levels: a 1-unit increase in the digital economy index corresponds to a 0.173-unit rise in the urban-rural integration index ($p<0.01$). This effect persists across instrumental variable estimation and multiple robustness checks.

Second, green innovation and optimized capital allocation constitute two key transmission channels through which the digital economy empowers urban-rural integration. The mediating effect of green innovation accounts for 35.1% of the total effect, and the mediating effect of capital allocation optimization accounts for 37.6%.

Third, the promoting impact of the digital economy exhibits obvious heterogeneity. The driving force is stronger in eastern regions, regions with advanced infrastructure and abundant human capital, which reflects the "infrastructure threshold" and "human capital threshold" for digital economy-enabled urban-rural integration.

Fourth, the digital economy has significant positive spatial spillover effects on urban-rural integrated development. Spatial spillover contributes 71.7% of the total effect, serving as an important channel through which the digital economy affects urban-rural integration.

5.2. Policy Implications

First, expand investment in digital infrastructure to bridge the urban-rural digital divide. Digital infrastructure construction should be prioritized to advance urban-rural integrated development. Accelerate the deployment of new infrastructure including rural broadband networks, 5G base stations and big data centers. More investment should be directed toward central, western and rural areas to narrow regional digital gaps and consolidate material foundations for the digital economy to empower urban-rural integration .

Second, stimulate the mediating function of green innovation and advance green low-carbon transformation in urban and rural areas. Incentive mechanisms for green innovation should be improved. Market-oriented instruments such as green credit, green taxation and carbon emission trading can guide enterprises to increase R&D investment in green technologies. Meanwhile, promote the popularization and application of green technologies, and translate green innovation achievements into tangible drivers of urban-rural integrated development .

Third, improve capital allocation efficiency and expand rural financing channels. Vigorously develop digital inclusive finance to lower the threshold and costs of financial services in rural areas. Improve rural property rights trading platforms to revitalize idle rural assets including land and housing. Guide orderly participation of social capital in rural revitalization and ease capital constraints on rural development .

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Fourth, strengthen awareness of spatial coordination and promote coordinated regional development. Break barriers of administrative divisions, establish cross-regional cooperation mechanisms for the digital economy, and facilitate the flow and sharing of digital technologies. Encourage regions with mature digital economy development to drive urban-rural integration in surrounding areas via industrial transfer, technical assistance and talent exchange, forming a sound pattern of coordinated regional development.

5.3. Research Limitations and Prospects

This research has certain limitations. Restricted by data availability, the indicator system measuring urban-rural integrated development can be further optimized. This paper only examines two transmission paths, namely green innovation and capital allocation; the digital economy may influence urban-rural integration via other channels. In addition, only provincial panel data are adopted. Future research can adopt prefecture-level or county-level data for refined analysis and improve estimation accuracy.

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