Research on the Spatial Effects of Digital Economy Development Under the Perspective of Rural Revitalization

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Abstract: This study examines the impact mechanism of digital economic growth on rural revitalization. Using benchmark regression models and spatial econometric models for empirical analysis, this study also established a mediation effect model to test the indirect impact of digital economic growth on rural revitalization. The results indicate that the development of the digital economy has had a positive impact on rural revitalization, which has been confirmed through robustness testing. In addition, research has shown that the development of the digital economy has a significant spatial spillover effect on rural revitalization, which can be improved by accumulating human capital. The heterogeneity analysis of the eastern, central, and western regions of China shows that compared to the eastern regions, the impact of digital economic growth on rural revitalization is more significant in the central and western regions. The marginal effect gradually increases from the east to the central and then to the west. Based on these findings, the study proposes relevant suggestions to provide strategic basis for addressing key issues in rural revitalization and development.

Keywords: Digital Economy; Rural Revitalization; Human Capital; Spatial Effects

1. Introduction

The digital economy can promote the modernization of agricultural production management. Traditional agricultural production methods often yield lower outputs and are greatly influenced by natural environments. With the assistance of modern information technology, intelligent and technologically advanced agricultural practices can be developed, facilitating the revitalization and development of rural areas. According to Elhorst, J. P., the development of the digital economy can effectively lead to enhanced urban innovation capabilities, accelerate the digitization and industrialization of urban industries, and empower rural revitalization strategies [1]. Although the impact of digital economy development on employment in the secondary sector, high-tech, and high-employment industries is relatively small, it effectively drives the transformation of employment structures towards high technology, providing a large pool of talent for the transformation of rural revitalization towards digital construction with high skills and manufacturing capabilities. The interaction of human capital, technology, and policies influences the development of the digital economy. Li Dan and Cen, T. et al. suggest that the opening of broadband internet increases opportunities for rural workers to access employment information, which can bring more entrepreneurial and non-agricultural employment opportunities to farmers, attract talent back to rural areas, cultivate new professional farmers, unleash the enormous employment potential of rural areas, and create a favorable development environment for rural revitalization [2]. Keller, W. believes that narrowing the digital divide between developed and developing countries hinges on material capital, human capital, and economic-policy environments. Talent is the most important factor of production and the fundamental driving force for economic growth and the promotion of digital and technological economic development. Talent is imperative for labor force investment [3].

In summary, prior research has predominantly focused on examining the role of the digital economy in rural revitalization from a singular perspective and has recognized its spatial spillover effect. However, there remains a lack of thorough investigation into the specific characteristics of these spatial spillovers and a comprehensive analysis of their heterogeneity.

To address this gap, this study employs both baseline regression and spatial econometric models to assess the impact of digital economy development on rural revitalization with human capital as the mediating factor. Furthermore, it endeavors to provide recommendations based on its findings.

2. Research Design

2.1 Data Source

The study used data from 31 Chinese provinces, municipalities and autonomous regions between 2016 and 2022. Data sources include China Statistical Yearbook, China Rural Statistical Yearbook, Peking University Digital Financial Inclusion Research Center, and China Digital Economy Development Report. To deal with missing data for some provinces, linear interpolation is used. To reduce the effect of heteroscedasticity on the sample, all variables are transformed using natural logarithms.

2.2 Indicator Selection

2.2.1 Explanatory Variable: Digital Economy Development (DED)

Building on the research findings of relevant scholars, this study develops an indicator evaluation system by selecting indicators from four key dimensions of the digital economy: digital finance, industrial digitization, digital industrialization, and the digital economic development environment. The specific indicators are detailed in Table 1.

Table 1. Evaluation System of Digital Economy Development Indicators

Comprehensive indicators	First level indicator	Secondary indicators
digital economy	digital finance	Extent of digital financial coverage
		Intensity of digital finance utilization
		Level of digital finance digitization
	Industrial digitalization	Quality of online mobile payment
		E-commerce sales as a share of GDP
		Percentage of enterprises engaged in e-commerce transactions
		Number of computers used per 100 people
		Number of websites per 100 companies
	Digital industrialization	Software product revenue to GDP ratio
		Information technology services to GDP ratio
		Ratio of total telecommunications business volume to GDP
	Digital economic development environment	Optical cable line length per square kilometer
		Mobile phone base stations per square kilometer
		Number of domains per square kilometer
		Number of Internet broadband access users

2.2.2 Dependent Variable: Rural Revitalization (RL)

The study has identified 15 secondary indicators across five dimensions, namely industrial prosperity, ecological livability, cultural civilization, governance effectiveness, and life affluence, based on the evaluation system of rural revitalization indicators in the Rural Revitalization Strategic Plan. These specific indicators are detailed in Table 2.

Table 2. Rural Revitalization Evaluation System

Comprehensive indicators	First level indicator	Secondary indicators
rural revitalization	Industry is booming	Stable economic growth
		Per capita income of rural residents
		Per capita output value of agriculture, forestry, animal husbandry and fishery
	Ecological and livable	Environmental space quality good rate
		Safe drinking water coverage
		Domestic waste disposal rate
	Rural customs and civilization	Average years of education for the rural population
		Number of cultural activity venues in townships
		Average years of education of rural population

	Effective governance	Agricultural infrastructure completion rate
		Sanitary toilet renovation rate
		Coverage rate of township social work stations
	live a prosperous life	Urban-rural income gap
		Engel coefficient of rural residents
		Proportion of households with private cars

2.2.3 Mediating Variable: Human Capital (HC)

Human capital refers to the capital possessed by laborers, including education and culture, with the primary component being the human capital enhanced through education. Education can promote the improvement of labor skills, cultural levels, and other comprehensive qualities of labor force. Research results indicate that the quality and capabilities of labor force play a significant role in rural development, as laborers with more education and training can better promote rural development. Therefore, this study uses the mean years of education provided by the Labor and Economic Research Center as the measure of human capital to examine the pathway through which digital economy development promotes rural revitalization via the mediating effect of human capital.

2.2.4 Control Variables:

Urbanization Level (UL) is defined as the ratio of urban population to total population within each province [4]. Technological Innovation (TL) is assessed using the natural logarithm of domestic patent applications, chosen for its data reliability [5]. Rural Entrepreneurship (RE) measures the proportion of rural village and private enterprise employees to the total village population, indicating higher activity levels in rural entrepreneurship [6]. Economic Development Level (EDL) is determined by per capita GDP [7]. Financial Support for Agriculture (FSF) measures spending on agricultural, forestry, and water affairs as a proportion of total general budget expenditure, following methodologies used by scholars [8]. Education Expenditure Level (EEL) quantifies local education spending as a percentage of total general budget expenditure, based on established scholarly approaches [9].

2.3 Model Design

2.3.1 Baseline Regression Model

This study uses sample data to empirically examine the impact of digital economy development on rural revitalization and establishes a baseline regression model, as follows:

$$RL_{\mathrm{it}} = \alpha_0 + \alpha_1 DED_{it-1} + \varphi W_{it} + u + \lambda_t + \varepsilon_{it} \quad (1)$$

In this model, RL represents rural revitalization, α_0 represents a constant term, DED represents the digital economy (lag one period to weaken reverse causality), W represents all control variables, i represents the province, t represents the year, and φ is a measure of the control variable pair The impact of rural revitalization [10].

2.3.2 Spatial Econometric Model

In order to deeply analyze the intrinsic relationship between digital economic development and rural revitalization, this study constructs a spatial Durbin econometric model, as follows:

$$RL_{it} = \beta_0 + W_{i,t} o + \sum_{j=1}^{n} X_{ij} W_{i,t} \kappa + \sum_{j=1}^{n} X_{ij} RL_{i,t} \varpi + \mu_i + \lambda_t + \varepsilon_{it} (j \neq 1) \quad (2)$$

In this model, β0 represents the intercept term, i denotes the specific province, t denotes the year, j represents provinces other than Province i, W stands for the explanatory variables and all control variables, XW signifies the exogenous interaction effects of all variables, XRL indicates the endogenous interaction effects of the explained variables, and o represents estimates of the explanatory variables and all control variables. β is used to estimate parameters for spatial interaction terms between explanatory and control variables, while ρ represents the spatial autocorrelation coefficient [11].

2.3.3 Mediating Effect Model

This study constructs the following mediating effect model:

$$HC_{it} = \gamma_0 + \gamma_1 DED_{it-1} + \sigma W_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (3)$$

$$RL_{it} = \omega_0 + \omega_1 DED_{it-1} + \omega_2 HC_{it} + \psi W_{it} + \mu_i + \lambda_t + \varepsilon_{it} \quad (4)$$

In this model, HC represents human capital, γ_1 is a measure of the human capital effect under the development of the digital economy, ω_1 is the impact of digital economic development on rural revitalization through human capital, ω_2 is the impact of human capital on rural revitalization, and σ,ψ represents the control variable Estimated value. When γ_1 is significant, if ω_2 passes the significance test and the

estimated coefficient or significance level of ω_1 is lower than the baseline regression, it means that the transmission mechanism has been established.

3. Empirical Analysis

3.1 Benchark Regression

As indicated in Table 3, the estimated coefficient for the key explanatory variable, digital economy development (DED), is 0.115, which is statistically significant at a noteworthy level. This suggests that the advancement of the digital economy significantly enhances the implementation of rural revitalization strategies. Therefore, relevant authorities should prioritize digital economy initiatives and intensify efforts in digital rural development to sustain ongoing momentum in rural revitalization. Among the control variables, the coefficient estimate for urbanization level (UL) is 0.960, significant at the 1% level, indicating that regions with higher urbanization levels also experience higher levels of rural revitalization. Urbanization introduces new growth dynamics into rural revitalization efforts. The coefficient estimate for technological innovation (TL) is 0.032, though statistically insignificant, suggesting that while current technological innovations somewhat support rural revitalization, their impact remains limited.

The coefficient estimate for economic development level (EDL) is -0.048, significant at the 5% level, indicating that widening income disparities between urban and rural areas within a region increase the challenges in implementing rural revitalization strategies. This finding aligns with reality, as significant urban-rural income gaps attract rural labor and talent to urban areas, reducing the attractiveness of rural areas for workers. Consequently, rural areas may face difficulties in attracting necessary talent and technology, hindering their revitalization. In summary, digital economy development plays a crucial role in advancing rural revitalization efforts

Table 3. Baseline Regression Results

variable	RL
DED	0.115***
	(4.28)
UL	0.960***
	(5.60)
TL	0.032
	(0.00)
RE	-0.625***
	(-4.15)
EDL	-0.048**
	(-1.25)
FSF	0.453
	(0.75)
EEL	0.562
	(3.24)
N	260
F-Value	152.1
R2	0.902
Note: *, ** and *** indicate significance at the 10%, 5% and 1% levels respectively, and the t value is in parentheses, the same below.	

3.2 Regression Results of Spatial Econometric Model

Table 4 shows the results of testing the impact of digital economy development on rural revitalization by using Elhorst spatial econometric test, and it is considered that spatial Durbin model is the most suitable. In column (1), the estimated coefficient of digital economy development is 0.015, which is statistically significant and positive. Similarly, the estimated coefficient of the spatial direct effect of the development of digital economy is also significantly positive. This shows that the development of digital economy not only promotes the rural revitalization in the region, but also has a significant spatial spillover effect on the rural revitalization in the surrounding areas. For further analysis of variable changes, a partial decomposition is used to distinguish between direct and indirect effects. As can be seen from columns (3) and (5), both the direct and total effects of digital economy development on rural revitalization are statistically significant. The development of the digital economy directly promotes the revitalization of rural areas and affects the revitalization of other regions through spatial spillover effects. This consistency highlights the role of digital economy development in promoting local and regional rural revitalization, highlighting the existence of spatial spillover effects

.Table 4. Econometric Model Regression Results

variable	direct effect	indirect effect	direct effect	indirect effect	total effect
	(1)	(2)	(3)	(4)	(5)

DED	0.015**	0.035***	0.015**	0.036***	0.050***
	(0.008)	(0.006)	(0.007)	(0.014)	(0.016)
UL	0.047	-0.568***	0.025	0.564***	0.585***
	(0.115)	(0.210)	(0.012)	(0.210)	(0.201)
TL	0.070	0.435***	0.080	0.420***	0.490***
	(0.060)	(0.105)	(0.060)	(0.115)	(0.115)
RE	0.060	-0.078***	0.061***	-0.076***	-0.020
	(0.016)	(0.030)	(0.016)	(0.026)	(0.036)
EDL	0.020**	0.120***	0.132***	0.008*	0.068*
	(0.012)	(0.035)	(0.042)	(0.005)	(0.051)
FSF	0.140*	0.605*	-0.020	1.158***	0.0543***
	(0.060)	(0.228)	(0.019)	(0.136)	(0.140)
EEL	0.052**	0.256***	0.416***	-0.315***	-0.290**
	(0.020)	(0.095)	(0.068)	(0.108)	(0.116)
N	260	260	260	260	260
R^2	0.560	0.560	0.560	0.560	0.560

3.3 Mediation Effect Results

Table 5. Mediation Effect Regression Results

variable	(1)	(2)	(3)
	RL	HC	RL
DED	0.135***	0.025**	0.115**
	(4.30)	(4.01)	(3.15)
HC			1.160**
			(2.65)
UL	0.962	-0.025	0.980***
	(5.62)	(-0.85)	(5.69)
TL	0.023	0.150	-0.019
	(0.00)	(0.75)	(-0.15)
RE	-0.625***	-0.105	-0.615***
	(-4.15)	(-0.51)	(-4.10)
EDL	-0.048	-0.024***	-0.025
	(-1.23)	(-3.62)	(-0.57)
FSF	0.435	2.38***	-2.361*
	(0.75)	(24.12)	(-1.90)
EEL	-0.621***	-0.105	-0.612
	(-4.15)	(-0.45)	(-4.10)
N	260	260	260
F	165.2	72.36	150.3
R^2	0.810	0.635	0.815
Is it significant?	Yes		

In Table 5, the impact path of digital economy development on human capital in rural revitalization is analyzed. Column (2) gives the results on the impact of digital economy development on human capital. The estimated coefficient of digital economy development is 0.025, which is significant at the 1% level. This shows that the development of the digital economy has significantly enhanced the attractiveness of rural areas for human capital. Digital economy initiatives attract the workforce to additional education and training, thereby improving their overall qualifications and professional skills to prepare them for entry into the high-tech sector, the report noted.

In column (3), the examination is conducted after adding human capital as a mediating variable. The coefficient estimate of the mediating variable is 0.115, and it is significant at the 5% level. This indicates that the inclusion of human capital can promote rural revitalization. Digital economy development requires high levels of knowledge and professional skills from laborers, which will encourage them to undergo more education and training to enhance their educational qualifications and skill sets. High-quality human capital is crucial for promoting rural revitalization. Therefore, it can be seen that the mediation effect exists, whereby digital economy development can promote rural revitalization through human capital.

3.4 Heterogeneity Analysis

The study divided the sample into three main regions, eastern, central, and western, for the change in test results. As shown in column (1) of Table 6, the estimated coefficient of digital economic development is positive, but it lacks statistical significance, indicating that digital economic development has little impact on rural revitalization in the eastern region. This may be due to the relatively high level of digitization in the eastern rural region compared to the Midwest, which undermines the apparent impact of further development of the digital economy. In contrast, the estimated coefficient of digital economic development in column (2) is

statistically significant at the 1% level, suggesting that digital economic development has a significant positive impact on rural revitalization in the central region.

Likewise, in column (3), the estimated coefficient of digital economic development is quite positive, emphasizing the important role in promoting the revitalization of rural areas in the western part of the country. In general, digital economic development has a more pronounced impact on rural revitalization in the midwestern region compared to the eastern region. In terms of trends in the trend, the middle, and the west, digital economic development is playing an increasing role in rural revitalization, and the influence of these regions is also steadily increasing.

Table 6. Heterogeneity Analysis

variable	east	central	west
DED	0.018	0.072***	0.092***
	(0.016)	(0.030)	(0.025)
UL	1.268***	0.260	0.430**
	(0.351)	(0.325)	(0.218)
TL	0.460***	0.473*	0.645**
	(0.125)	(0.230)	(0.218)
RE	-0.185***	0.005	-0.050
	(0.038)	(0.056)	(0.054)
EDL	0.135**	0.092*	0.043
	(0.335)	(0.015)	(0.053)
FSF	0.452***	0.438*	0.655**
	(0.126)	(0.236)	(0.289)
EEL	-0.185***	0.095*	0.035
	(0.036)	(0.053)	(0.051)
N	120	120	120
R^2	0.752	0.860	0.840

4. Conclusion

The results of the study highlight the important role of digital economic development in driving rural revitalization. The development of digital economy not only directly affects rural revitalization, but also shows considerable spatial spillover effect. Further research has shown that these spillovers work primarily through the enhancement of human capital, thereby contributing to rural revitalization efforts. In addition, the analysis of East, Central and Western regions of China shows that the impact of digital economic development on rural revitalization is particularly obvious in the Midwest compared to the eastern regions. Marginal effects increase sequentially from east to center to west.

This study provides valuable insights into the relationship between digital economic development and rural revitalization. By clarifying the mechanisms by which the digital economy promotes rural revitalization, it will inform policymakers and relevant sectors to formulate more effective policies and strategies to promote sustainable rural economic development.

Despite the achievements of this study, some limitations should be acknowledged. First, the models and methods used can be further refined and validated, particularly in understanding the complex links between the digital economy and rural revitalization. Secondly, the research in this paper is mainly focused on China, and future research can explore a wider geographical context and draw more comprehensive conclusions. Finally, given the dynamics of the digital economy, future research could explore the long-term impact and sustainability of digital economic development on rural revitalization.

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