Study on the Impact of Digital Economy Development on Regional Economic Resilience

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Abstract. This study utilizes panel data from 30 provinces and municipalities in China from 2014 to 2023 to construct an indicator system for digital economy and regional economic resilience. Entropy weighting is employed to measure the development levels of both, and an intermediary model, threshold effect model, and spatial Durbin model are applied to empirically analyze the impact of digital economy development on regional economic resilience. The findings reveal that the development of the digital economy not only directly enhances regional economic resilience but also generates an intermediary effect by promoting human capital accumulation and innovation capacity enhancement. Its impact exhibits non-linear characteristics, with more significant effects in regions where human capital and innovation capacity surpass threshold values. Additionally, spatial spillover effects exist, positively influencing the economic resilience of surrounding regions. The study indicates that developing the digital economy is an important pathway to enhancing regional economic resilience.

Keywords: digital economy, regional economic resilience, mediating effect, threshold effect

1 Introduction

Against the dual backdrop of heightened global economic risks and China's economic transformation, enhancing regional economic resilience has become a critical task for coping with various shocks. As a new economic model characterized by data resources as its key element and modern information networks as its primary carrier, the digital economy is profoundly reshaping the economic landscape through industrial digitization and digital industrialization. It has demonstrated remarkable risk-resistance capabilities during emergencies such as the pandemic. However, China faces pronounced imbalances in digital economic development across regions, with substantial gaps in infrastructure and innovation capacity between the eastern and central-western regions. The underlying mechanisms through which these disparities impact economic resilience warrant further investigation.

H. Li et al. (eds.), *Proceedings of the 2026 5th International Conference on Big Data Economy and Digital Management (BDEDM 2026)*, Advances in Economics, Business and Management Research 383,
https://doi.org/10.2991/978-94-6239-640-1_10

Theoretically, Liu Jun et al. (2020) established a provincial-level digital economic development evaluation framework based on three dimensions—internet infrastructure, informatization, and digital transactions—providing a crucial reference for subsequent research[1]. Jin Zhaohui (2024) further extended this research to the prefecture-level city dimension, using the number of digital economy invention patents to measure development levels[2]. The concept of economic resilience, originating from Graaff (2002), describes a region's capacity to maintain stability and achieve transformation in response to shocks[3]. Luo Gongli et al. (2024) noted that economic resilience is influenced by spatial connectivity, industrial diversification, and institutional innovation, exhibiting significant spatial spillover effects[4]. In empirical studies, Ma Li (2024) analyzed the intrinsic mechanism by which the digital economy influences economic resilience from the perspective of industrial structure rationalization and upgrading[5]. Tong Sujuan (2023) examined the coupling relationship between the digital economy and regional economic resilience using entropy and coefficient of variation methods based on data from cities along the Yangtze River Economic Belt[6]. Chen Congbo (2021) validated the promotional role of the digital economy in the Yangtze River Delta region using a spatial panel model[7].

Despite progress in existing research, the causal mechanisms, nonlinear characteristics, and spatial effects linking the digital economy and regional economic resilience remain underexplored. Most literature fails to systematically integrate influencing mechanisms and lacks an in-depth discussion of nonlinear effects and spatial dependencies. Against this backdrop, this study constructs an indicator system for the digital economy and regional economic resilience based on panel data from 30 Chinese provinces and municipalities (2014–2023). It employs entropy weighting to measure their development levels and utilizes mediation models, threshold effect models, and spatial Durbin models to empirically analyze the impact of digital economy development on regional economic resilience. Theoretically, this study systematically reveals that the digital economy enhances economic resilience through the mediating mechanisms of human capital accumulation and innovation capacity enhancement. It also verifies the existence of threshold characteristics with increasing marginal benefits and spatial spillover effects. Practically, the findings provide evidence for governments to formulate differentiated regional policies, helping overcome threshold constraints on human capital and innovation capacity, promoting coordinated regional development, and offering scientific support for building a new dual-circulation development pattern, advancing Digital China, and fostering a resilient China.

2 Research Design

2.1 Model Setting

To examine the impact of the digital economy on regional economic resilience, the following baseline model is constructed:

$$rx_{jit} = \alpha_{j0} + \alpha_{j1} lnsz_{it} + \alpha_{jc} Z_{it} + \varepsilon_{jit} \quad (1)$$

Where,rx_{jit} represents the regional economic resilience index,$lnsz_{it}$ represents the level of digital economic development, andZ_{it} represents the set of control variables. To delve deeper into the mechanisms through which the digital economy impacts economic resilience, this paper further constructs a mediation effect model:

$$N_{jit} = \beta_{j0} + \beta_{j1} lnsz_{it} + \beta_{jc} Z_{it} + \varepsilon_{jit} \tag{2}$$

$$rx_{1it} = \gamma_{j0} + \gamma_{j1} lnsz_{it} + \gamma_{j2} N_{jit} + \gamma_{jc} Z_{it} + \varepsilon_{jit} \tag{3}$$

In the equation, $N_{jit}$is the mediating variable,$j = 1、2$, representing human capital and innovation capability respectively.β_{j0} is the constant term, β_{j1}、β_{jc} are the regression coefficients of each variable; γ_{j1}、γ_{j2}、$\gamma_{jc}$are the regression coefficients of each variable.

Given that the impact of the digital economy on regional economic resilience may exhibit nonlinear characteristics, this paper constructs a threshold effect model, using a single threshold as an example:

$$rx_{1it} = \varphi_{j0} + \varphi_{j1} lnsz_{it} \times I(\cdot)\left(th_{jit} \le \theta\right) + \varphi_{jc} Z_{it} + \varepsilon_{jit} \tag{4}$$

Among them,θ is the threshold value to be estimated;I(·)is the indicator function; $th_{jit}$is the threshold variable,$j = 1、2$ respectively represent the human capital and innovation capability threshold variables; φ_{j0} is the constant term, φ_{j1}、φ_{j2}、φ_{jc} are the regression coefficients of each variable in the threshold model; other letters have the same meanings as above.

To examine the spatial dependence and spillover effects present in the digital economy, this paper constructs the following spatial Durbin model:

$$rx_{1it} = \alpha_{j0} + \rho W rx_{1it} + \lambda_{j1} W lnsz_{it} + \alpha_{j1} lnsz_{it} + \lambda_{jc} W Z_{it} + \alpha_{jc} Z_{it} + \varepsilon_{jit} \tag{5}$$

Among them, W is the spatial weight matrix, ρ is the spatial autoregressive coefficient,λ_{j1} and λ_{jc} are the coefficients of the digital economy development index and the spatial interaction term of control variables, and other letters have the same meaning as above.

2.2 Variable Setting and Selection

Construction and Measurement of the Digital Economy Development Index Evaluation Indicator System.

This study draws on the research of Li Xiaozhong et al. (2022)[8] to construct a digital economy development index comprising eight secondary indicators from three dimensions: digital infrastructure, supporting industry scale, and digital application capability, as shown in Table 1. Based on data continuity and availability, data from 30 provinces, autonomous regions, and municipalities (excluding Tibet and Hong Kong, Macao, and Taiwan regions) in China from 2014 to 2023 were selected, and the entropy method was used to measure the level of digital economy development.

Table 1. Evaluation Indicator System.

Primary Indicators	Second-level indicators	Unit	Attribute
Digital Infrastructure	Telecommunications services per capita	Yuan	+
	Mobile phone penetration rate	units/100 people	+
	Internet broadband access ports	Ten thousand	+
	Length of optical fiber lines	Kilometers	+
	Mobile telephone exchange capacity	Ten thousand	+
Supported industrial scale	Software business revenue	billion	+
Digital application capability	Internet penetration rate	%	+
	Proportion of population with higher education	%	+

Construction and Calculation of the Regional Economic Resilience Index Evaluation Indicator System.

The Regional Economic Resilience Index (rx_{1it}) evaluation indicator system is constructed from three dimensions: resistance and recovery capacity, adaptation and regulation capacity, and innovation and transformation capacity. The specific indicators are shown in Table 2:

Table 2. Construction and Calculation of the Regional Economic Resilience Index Evaluation Indicator System.

Primary Indicators	Second-Level Indicators	Unit	Attribute
Resilience and Recovery Capacity	Regional Gross Domestic Product	billion	+
	Per capita GDP	yuan	+
	Rural residents' per capita disposable income	yuan	+
	Per capita disposable income of urban residents	yuan	+
	Level of openness to the outside world	%	-
Adaptability and adjustment capacity	Unemployment rate	%	-
	Per capita disposable income of residents	yuan	+
Innovation and transformation capacity	Industrial upgrading	%	+
	Urbanization rate	%	+
	Local government fiscal expenditure	%	+

Mediating Variables.

Human capital (hum_{it}) is measured by the average years of education of individuals in region i in year t, where the average years of education for primary, junior high,

senior high, and college education are 6, 9, 12, and 16 years, respectively; innovation capacity (zl_{it}) is measured by the number of patent authorizations in region i in year t.

Control Variables.

The following control variables were selected for this study: (1) Labor input (l_{it}), represented by the number of employed individuals in the region. (2) R&D intensity (rd_{it}), represented by the proportion of R&D expenditure to regional GDP. (3) Foreign direct investment (fdi_{it}), represented by the stock of registered foreign investment at the end of the year in each region. (4) Capital investment (k_{it}), represented by the amount of fixed asset investment.

3 Empirical Analysis

3.1 Descriptive Statistical Analysis of Key Variables

This study uses panel data from 30 provincial-level regions in China (excluding Tibet, Hong Kong, Macao, and Taiwan) from 2014 to 2023. The entropy method calculates both the digital economy development index and the regional economic resilience index. To reduce dimension differences and heteroskedasticity, all variables except the dependent one are log-transformed. Data come from the China Statistical Yearbook, and descriptive statistics are shown in Table 3.

Table 3. Descriptive Statistics.

Variable Category	Variable Name	observed value	Mean	Variable symbol	Minimum value	Maximum value
Dependent variable	Regional economic resilience (rx)	300	0.227	0.104	0.092	0.668
Core explanatory variable	Digital Economy Development Index (lnsz)	300	-2.271	0.675	-4.500	-0.600
Mediating variable	Human capital (lnhum)	300	2.239	0.092	2.011	2.548
	Innovation capacity (lnzl)	300	10.59	1.345	6.428	13.68
Control variables	Labor input(lnl)	300	7.584	0.781	5.545	8.864
	Capital investmen (lnk)	300	9.742	0.829	7.914	11.12
Variable Category	Variable Name	observed value	Mean	Variable symbol	Minimum value	Maximum value
Control variables	R&D intensity (lnrd)	300	-4.648	0.601	-6.391	-3.659
	Foreign Direct Investment(lnfdi)	300	7.218	1.439	3.434	11.49

3.2 Benchmark Regression

The results of the benchmark regression are shown in Table 4. The estimated coefficient of the core explanatory variable lnsz is significantly positive, indicating that the development of the digital economy has a significant positive impact on regional economic resilience. The results in column (2) show that labor input, capital input, R&D intensity, and foreign direct investment are all significantly positively correlated with regional economic resilience, suggesting that promoting employment, expanding investment, strengthening R&D, and attracting foreign investment enhance financial stability. Columns (3) to (5) further show that the digital economy also significantly impacts the three secondary indicators of resistance to recovery, adaptation and adjustment, and innovation and transformation at the 1% level.

Table 4. Results of benchmark regression analysis.

	(1)	(2)	(3)	(4)	(5)
	rx	rx	rx1	rx2	rx3
lnsz	0.046***	0.037***	0.027***	0.005***	0.005***
	(0.003)	(0.003)	(0.003)	(0.001)	(0.001)
lnl		0.061***	0.085***	0.003*	-0.027***
		(0.021)	(0.017)	(0.004)	(0.008)
lnk		0.022***	0.024***	0.003***	-0.005**
		(0.005)	(0.004)	(0.001)	(0.002)
lnrd		-0.038***	-0.026***	-0.006***	-0.006*
		(0.008)	(0.006)	(0.002)	(0.003)
lnfdi		-0.006***	-0.007***	-0.002***	0.004***
		(0.002)	(0.002)	(0.000)	(0.001)
cons	0.487***	-0.286*	-0.640***	0.015	0.340***
	(0.007)	(0.158)	(0.125)	(0.031)	(0.063)
	(1)	(2)	(3)	(4)	(5)
	rx	rx	rx1	rx2	rx3
N	300	300	300	300	300
R2	0.979	0.983	0.980	0.979	0.969
Adj-R^2	0.976	0.980	0.976	0.975	0.963

Note: The values in parentheses in the table represent robust standard errors; ***, **, and * indicate significance at the 1%, 5%, and 10% levels, respectively. The same applies below.

3.3 Mediating Effect Analysis

This paper draws on the methods of Jiang Ting (2022)[9] and Li Wanli et al. (2023)[10] to systematically examine the direct impact of the digital economy on regional eco-

nomic resilience, its influence on human capital and innovation capacity, as well as the mediating mechanisms through which these factors affect regional economic resilience. The results in Table 5 indicate that the digital economy not only directly promotes regional economic resilience (Column 1 and 4) but also exerts a significant mediating effect through enhancing human capital (Column 2 and 3) and innovation capacity (Column 5 and 6), suggesting that it can indirectly improve regional economic resilience by strengthening innovation capacity and other pathways.

Table 5. Estimation Results of the Mediating Effect Model.

	(1)	(2)	(3)	(4)	(5)	(6)
	rx	lnhum	rx	rx	lnzl	rx
lnsz	0.037***	-0.004		0.037***	-0.083**	
	(0.003)	(0.003)		(0.003)	(0.036)	
lnhum			0.064**			
			(0.082)			
lnzl						-0.016**
						(0.007)
lnl	0.061***	0.057***	0.101***	0.061***	0.383*	0.109***
	(0.021)	(0.020)	(0.026)	(0.021)	(0.221)	(0.025)
lnk	0.022***	0.007	0.036***	0.022***	-0.122**	0.034***
	(0.005)	(0.005)	(0.006)	(0.005)	(0.055)	(0.006)
lnrd	-0.038***	0.013*	-0.053***	-0.038***	0.322***	-0.046***
	(0.008)	(0.008)	(0.010)	(0.008)	(0.085)	(0.010)
lnfdi	-0.006***	-0.001	-0.011***	-0.006***	0.096***	-0.010***
	(0.002)	(0.002)	(0.002)	(0.002)	(0.020)	(0.002)
_cons	-0.286*	2.095***	-0.924***	-0.286*	10.013***	-0.608***
	(0.158)	(0.146)	(0.253)	(0.158)	(1.641)	(0.198)
N	300	300	300	300	300	300
R2	0.983	0.981	0.975	0.983	0.989	0.975

3.4 Nonlinear Effect Analysis

The threshold effect test results are shown in Table 6. Both single-threshold and double-threshold significance passed the test, while the triple-threshold failed. Thus, the double-threshold model was selected. Using lnhum as the threshold variable, the dual values are 0.315 and 0.292; with lnzl, they are 0.292 and 0.267.

Table 6. Threshold Effect Test Results.

Threshold Variable	Threshold	Threshold Value	F value	P-value
lnhum	Single threshold	0.315	19.300	0.027
	Double threshold	0.315, 0.292	22.490	0.022
	Three thresholds	0.315, 0.292, 0.276	17.280	0.580
lnzl	Single threshold	0.292	43.340	0.030
	Double threshold	0.292, 0.267	27.490	0.015
	Three thresholds	0.292, 0.267, 0.260	7.530	0.145

The threshold regression results in Table 7 indicate that the lnsz has a positive promotional effect on regional economic resilience. Still, this effect is subject to non-linear constraints imposed by human capital and innovation capacity levels. When lnhum is below 0.315, the coefficient of lnsz is positive but not significant, indicating that when local human capital levels are low, the impact of the digital economy on regional economic resilience is limited; when lnhum exceeds 0.315, lnsz is significant at the 10% level, and the promotional effect is enhanced. Similarly, when lnzl is low, the impact of the digital economy is limited; when lnzl crosses the threshold value, lnsz is significant at the 5% level, and the promotional effect is significantly enhanced. The control variables lnl, lnk, lnrd, and lnfdi are all considerably positive, further confirming that the digital economy has a non-linear impact on regional economic resilience with increasing marginal benefits.

Table 7. Threshold Regression Estimation Results.

	(1)	(2)
	lnhum	lnzl
$\ln sz(th \leq \theta_1)$	0.016*	0.018*
	(-2.44)	(-2.16)
$\ln sz(\theta_1 < th \leq \theta_2)$	-0.001	-0.002
	(-0.02)	(-0.23)
$\ln sz(th > \theta_2)$	0.073*	-0.074**
	-2.630	(-3.10)
lnl	-0.125*	-0.166*
	(-1.49)	(-1.79)
lnk	0.098**	0.071*
	(-3.16)	(-2.56)
lnrd	0.018*	0.022*
	(-0.57)	(-0.71)
lnfdi	0.034***	0.034***
	(-4.47)	(-4.78)
_cons	0.102	0.683
	(-0.12)	(-0.83)
N	300	300
R2	0.680	0.700
Adj-R^2	0.670	0.690

3.5 Spatial Effect Analysis

This study employs the 0-1 adjacency matrix to calculate Moran's I index for spatial autocorrelation, with results presented in Table 8. From 2014 to 2023, the global Moran's I was significantly positive, indicating that there is a correlation between the digital economy development index and the regional economic resilience index of China's 30 provinces and municipalities, exhibiting a clear clustering pattern: regions with higher development levels are adjacent to each other, while lagging areas are also closely neighboring. Therefore, it is appropriate to conduct further analysis using spatial econometric models.

Table 8. Results of Spatial Autocorrelation Tests.

	(1)	(2)
	Regional Economic Resilience Index	Digital Economy Index
2014	0.240*** (2.631)	0.032*** (1.262)
2015	0.236*** (2.610)	0.019*** (1.486)
2016	0.248*** (2.716)	0.075*** (1.276)
2017	0.253*** (2.745)	0.102*** (1.236)
2018	0.256*** (2.772)	0.108** (1.339)
2019	0.252*** (2.774)	0.091*** (1.92)
2020	0.266*** (2.907)	0.085*** (1.134)
2021	0.294*** (3.101)	0.103*** (1.298)
2022	0.289*** (3.066)	0.110** (1.346)
2023	0.285*** (3.027)	0.121** (1.443)

Note: The values in parentheses are z-values.

This study identified an appropriate spatial econometric model by analyzing a series of test results. The LM test indicated that both spatial error and spatial lag models were significant at the 1% level, suggesting the presence of substantial spatial dependence; the LR and Wald tests were both significant at the 1% level, supporting the selection of the spatial Durbin model (SDM); the time-individual fixed effects test was necessary, thus adopting dual fixed effects; The Hausman test results ($p < 0.05$) rejected the null hypothesis, further confirming the use of fixed effects, the specific results are shown in Table 9. The SDM with dual fixed effects was ultimately selected for estimation.

Table 9. Model Test Results.

Model Tests	Statistic	Statistic
LM test	LM error	37.364***
	Robust LM error	9.309***
	LM lag	29.688***
	Robust LM-lag	1.633
Wald test	Wald-SDM/SAR	23.220***
	Wald-SDM/SEM	16.540***
LR test	LR-SDM/SAR	17.830***
	LR-SDM/SEM	36.980***
Time-individual fixed	LR-both/time	221.350***
	LR-both/individual	662.090***
Hausman test	fe/re	71.930***

The spatial Durbin model estimation results in Table 10 show that the spatial autoregressive coefficients are significantly positive at the 10% level, consistent with Moran's I conclusion, supporting the use of spatial econometric models. The direct and total effects of lnsz are both significantly positive at the 1% level, indicating that the local digital economy can effectively enhance economic resilience and improve response and recovery capabilities. Additionally, the digital economy exhibits significant positive spatial spillover effects on surrounding regions, enhancing financial resilience in neighboring areas.

Table 10. Estimation results of the spatial econometric model

rx	(1)	(2)
	Main	Wx
lnsz	0.032***	0.047**
	(0.008)	(0.005)
Direct effect	0.033***	
	(0.008)	
Indirect effect	0.013	
	(0.009)	
Total effect	0.046***	
	(0.012)	
ρ	0.305*	
	(0.177)	
sigma2_e	0.001***	
	(0.001)	
time	Yes	
Individual	Yes	
N	300	
R^2	0.823	

4 Conclusions and Suggestions

This paper establishes a comprehensive evaluation system for the relationship between digital economic development and regional economic resilience, employs the entropy method for measurement, and utilizes mediation effects, threshold effects, and spatial Durbin models to empirically analyze the impact of the digital economy on regional economic resilience. The study found that: First, the digital economy not only directly promotes regional economic resilience but also produces a significant mediating effect by enhancing human capital and innovation capabilities; Second, heterogeneity tests were conducted on the research sample from two dimensions—different geographical locations (eastern, central, and western regions) and different administrative divisions (municipalities directly under the central government and non-municipalities directly under the central government). The results show that the digital economy has a stronger resilience-enhancing effect on eastern regions and municipalities directly under the central government; Third, the impact of the digital economy exhibits threshold effects based on human capital and innovation capabilities, with the promotional effect significantly strengthening after crossing the threshold value, demonstrating a non-linear impact with increasing marginal benefits; Fourth, the results of the spatial Durbin model indicate that the development of the digital economy not only has a positive impact on the resilience of the local economy but also generates positive spillover effects on surrounding regions.

Based on the research conclusions, the following policy recommendations are proposed: First, strengthen the construction of digital infrastructure, proactively plan the "cloud, network, and endpoint" information infrastructure, and enhance support for core digital infrastructure technologies such as 5G enhancement technologies and 6G technology research and development, to promote the digital and intelligent transformation of traditional infrastructure. Second, promote the coordinated development of the digital economy in eastern, central, and western regions, increase policy support for infrastructure in underdeveloped areas, establish a regional mechanism for sharing the benefits of digital economic development, take 5G new infrastructure as a starting point, encourage enterprise investment and government procurement of services, and promote the balanced layout of new infrastructure. Third, strengthen the cultivation and introduction of digital talent, support universities in establishing digital majors and developing online open courses, promote "Internet+" teaching and on-the-job training, and attract professional talent through optimized innovation ecosystems and talent policies. Fourth, promote the innovative development of the digital economy, leverage regional industrial advantages based on local conditions, and promote the deep integration of innovation chains, industrial chains, capital chains, and policy chains to continuously improve the level of digital economic development and better leverage the role of the digital economy in enhancing the resilience of the regional economy.

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