The Digital Economy Drives the Improvement of Regional Innovation Capacity

--Intermediary Test Based on "Three-stage" Knowledge Flow

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Abstract. Innovation is the core driving force for high-quality economic development. In the new era, it is necessary to seize development opportunities, continuously improve regional innovation capabilities, and promote development through innovation. At present, the rapid development of digital economy in various regions is affecting regional innovation capacity in many ways, and is expected to improve the quality and efficiency of regional innovation and development. Taking 30 provinces, autonomous regions and municipalities in China from 2011 to 2020 as research samples, this paper uses coupling coordination degree model to measure the digital economy level at the provincial level, and empirically tests the mechanism of digital economy driving the improvement of regional innovation ability. The results show that digital economy can significantly promote regional innovation ability. Moreover, the digital economy promotes regional innovation capacity through knowledge flow. Further research shows that digital economy can produce positive spatial spillover effect, and the innovation effect of provinces with high level of digital economy is stronger. Therefore, the digital economy will not only enhance its own regional innovation capacity, but also promote the innovation capacity of the surrounding region.

Keywords: digital economy; regional innovation; "three-stage" knowledge flow coupling; coordination degree; spatial Durbin model.

1 Research Background

As an important carrier of innovation and development, the improvement of regional innovation ability is crucial to high-quality economic development. However, at present, the improvement of regional innovation capacity still faces challenges due to the lack of impetus and the widening regional innovation gap [1]. The lack of improvement of regional innovation capacity and the widening gap have caused the lack of impetus for economic development and transformation and upgrading in innovation-backward regions, resulting in unbalanced regional economic development, which is

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not conducive to achieving high-quality economic development. According to the "China Regional Innovation Capability Evaluation Report", from 2011 to 2020, the comprehensive utility value of innovation capability in only one third of regions showed an upward trend, indicating the lack of driving force for innovation capability improvement in all regions. Therefore, in order to better promote high-quality economic development, it is necessary to narrow the regional innovation gap and realize coordinated development of regional innovation in the process of improving regional innovation capability.

At present, China has entered the digital era, and the development level of digital economy in various regions is getting higher and higher, which is expected to enhance the new driving force for regional innovation capacity, but this has the theoretical and practical inconsistency. In theory, the digital economy can bring into play the obvious effect of improving the regional innovation capacity and the radiating and driving effect of the innovation capacity in the surrounding regions, which is expected to change the development status of regional innovation capacity and promote the improvement of innovation capacity [2]. In reality, on the one hand, the effect of digital economy on the improvement of regional innovation capacity has not yet appeared; On the other hand, the radiating effect of the digital economy on the innovation capacity of the surrounding regions is not obvious, and even a siphon effect may occur [3]. The inconsistency between theory and reality indicates that the impact of digital economy on regional innovation capacity needs to be further studied. Further, to deepen the innovation effect of the digital economy, it is necessary to clarify its impact path, on this basis, determine key development regions to give play to the radiation effect of the digital economy, and ultimately change the development status of regional innovation capacity, and promote the improvement of regional innovation capacity.

2 Literature Review

In recent years, the world has entered the era of digital economy, and digital economy has become a hot research topic. Scholars at home and abroad have conducted research on digital economy from different aspects. As for the measurement of digital economy, most scholars choose to construct an indicator system. Wang Jun et al. [4] constructed an indicator system for the development level of digital economy from four dimensions: carrier of digital economy, digital industrialization, industrial digitalization and development environment of digital economy. Zhao Huixin et al.[5]selected five indicators related to the Internet and digital finance to build a digital economy indicator system. Sheng Bin et al.[6]constructed the digital economy development index from three dimensions: digital industry, industrial digital and digital governance. However, Wang Shiqiang et al.[7] believe that the digital economy will make enterprises discriminate in pricing, reduce product quality and damage social welfare. Yin Qiaoyi et al.[8] believe that the digital economy will cause unbalanced transactions, information asymmetry and data leakage among enterprises, resulting in high risk of enterprise opportunism.

Close to the topic of this paper is the research on digital economy and regional innovation capability, mainly focusing on the impact of digital economy on regional innovation capability and its impact mechanism. From the perspective of the impact of digital economy on regional innovation ability, Zhang Jie et al.[9] believe that Internet development can promote the innovative development of cities and micro-enterprises in general. Yin Ximing et al. [10] believe that digital economy issues enhance the efficiency of regional innovation system and empower regional and industrial innovation development. From the perspective of the impact mechanism of digital economy on regional innovation capacity, Wu Ying et al.[11], based on the perspective of financing and intellectual property rights, empirically-concluded that digital economy can promote the improvement of regional innovation capacity through the impact mechanism of easing financing constraints and improving the protection level of intellectual property rights. Based on the perspective of innovation activity, Zhao Tao et al. [3] conducted research from the city level and found that stimulating mass entrepreneurship is an important mechanism for digital economy to release high-quality development dividends. With the continuous deepening of research in recent years, a few scholars have conducted a preliminary discussion on the spatial relationship between digital economy and regional innovation. Xu Sheng et al.[12] found that digital economy has spatial positive spillover effect under spatial adjacency matrix or geographic distance matrix after empirical analysis using spatial Durbin model. After a comprehensive review of relevant studies, it is found that the relationship between digital economy and regional innovation continues to attract the attention of scholars, mainly focusing on the impact and mechanism of action, while a few studies focus on spatial characteristics.

The possible marginal contributions of this paper are as follows: First, from the perspective of research, it focuses on the dynamic development level of the internal structure of the digital economy. Second, in terms of action mechanism, we should improve the index system of existing studies in measuring knowledge spillover and no longer focus on the influence of knowledge spillover, but conduct research from the whole stage of knowledge flow, and divide knowledge flow into three stages of comprehensive measurement: spillover, absorption and transformation. Third, the spillover effect of the digital economy is deeply revealed, and the role of the digital economy in the improvement of regional innovation capacity is explored under the dual factors of geographical location and economic development level.

3 Theoretical Analysis of Digital Economy and Regional Innovation Capability Enhancement

3.1 Digital Economy and Improvement of Regional Innovation Capacity

First, digital industrialization improves regional innovation ability by improving the efficiency of R&D knowledge exchange and realizing the optimization of resource allocation. Digital industrialization can subvert the inefficient knowledge exchange

methods of field learning in the past, and rapidly bring together multiple innovative subjects in the field through the services and platforms provided by the digital industry[13]. Digital industrialization can help enterprises to collect, integrate, process and analyze consumer data, break the information barriers between the consumer side and the innovation side, and effectively connect consumer demand with resource allocation.

Second, industrial digitalization improves regional innovation ability by stimulating innovation impetus of innovation subjects and triggering industrial correlation effect. Industrial digitalization can optimize the innovation process, such as integrating and gathering the data of each link in the innovation process, establishing virtual models, simulating and optimizing the innovation process. The strong correlation between innovation subjects in the industrial chain makes industrial digitalization not only improve its own innovation level, but also affect the innovation level of upstream and downstream industries in the industrial chain through the industrial correlation effect. Based on the above analysis, this paper proposes the following research hypotheses:

H1: The development of digital economy can drive the improvement of regional innovation capacity.

3.2 The Mediating Role of Knowledge Flow

In the digital economy, "instant messaging, video conferencing, cloud platform" and other new ways of online knowledge exchange make the traditional knowledge flow obviously break through the limitation of time and space. Strengthening the frequency of knowledge flow can effectively expand the effective stock of innovation knowledge of regional innovation subjects. In addition, the breakthrough of the time-space restriction of knowledge flow also enhances the efficiency of knowledge flow, which significantly shorens the path of knowledge flow and realizes the long-distance instantaneous flow of knowledge, thus reducing the lag of knowledge flow and enabling regional innovation subjects to receive external knowledge in time. Based on the above analysis, this paper proposes the following research hypotheses:

H2: Digital economy drives the improvement of regional innovation capacity through the mediating role of knowledge flow.

3.3 Spatial Spillover Effect of Digital Economy

First, digital industrialization exerts the spatial spillover effect by promoting the spatial flow of R&D knowledge and improving the mismatch of innovation resources. Digital industrialization makes the range of knowledge flow larger and the transmission efficiency also greatly improved. Through the technological precision matching provided by the digital industry, a certain innovation subject in the field of innovation and development is targeted to exchange research and development knowledge according to the actual needs of its innovation and development, so as to achieve efficient and accurate transmission. The resource search function and resource sharing platform provided by digital industrialization can broaden the scope of innovation

resource search and allocation, and promote the flow of innovation resources to the surrounding areas.

Second, industrial digitalization exerts a spatial spillover effect by stimulating the innovation motivation of innovation subjects in the surrounding areas and triggering the industrial correlation effect in the surrounding areas. Industrial digitalization has changed the external innovation environment and optimized the production and business processes of innovative products. Industrial digitalization enables enterprises to innovate on previous production equipment and technology, and constantly update technical equipment for technological innovation. The industrial correlation effect can make this technological innovation spill over into the industrial chain of the surrounding area. Based on the above analysis, the following hypothesis is proposed:

H3: The digital economy has a positive spatial spillover effect, which can promote the innovation capacity of the surrounding areas.

4 Research Design

4.1 Data Source

This paper selects the data of 30 provinces, autonomous regions and municipalities (except Tibet, Hong Kong, Macao and Taiwan) from 2011 to 2020 for research. Logarithms of all variables were taken, and the data mainly came from China's Regional Innovation Capability Evaluation Report and Guotai 'an Database.

4.2 Variable Selection and Description

1) Explained Variables.

Regional Innovation Capability (inv). This paper selects the comprehensive utility value of regional innovation capability in China's Regional Innovation Capability Evaluation Report compiled by China Science and Technology Development Strategy Research Group.

2) Core Explanatory Variables.

Digital Economy (dig).

The index system of digital economy is shown in Table 1.

Table 1. Two-dimensional coupling coordination evaluation index system of "Digital Industrialization - Industrial Digitalization"

variable	Primary index	Secondary index	Indicator specification
Development level of digital economy	digital industrialization	Communication output	Total telecommunications business (100 million yuan)
		Internet penetration rate	nternet Access/Total population of the region at the end of the year
		Electronic information manufacturing output	Electronic information manufacturing business revenue (100 million yuan)

	Industrial digitization	Software and information technology services outputs	Software and information technology services business revenue (billion yuan)
		Degree of intelligent transaction	Enterprise network platform product sales revenue (100 million yuan)
		Degree of intelligent manufacturing	Industrial robot installation density
		Degree of digital transformation	Enterprise Digital Transformation Index

3) Control Variables.

The control variables are as follows: (1)Marketization degree (sch); (2) Financial development level (jr); (3) Economic development level (rgdp); (4)Education level (edu); (5)Industrial structure (is).

4) Intermediary Variables.

Knowledge flow (zhishi). his paper constructs a "three-stage" comprehensive evaluation system for knowledge flow, and the detailed indicators are shown in Table 2.

Table 2. "three-stage" comprehensive evaluation system of knowledge flow

variable	imary index	Secondary index	measurement index
knowledge flow	knownledge spillover	Technology transaction spillover	Number of regional contracts for technology export (items)
		Industry-university-research cooperation spills over	Internal expenditure of R&D funds of universities and research institutes by enterprises (100 million yuan)
	Knowledge Assimilation	Inter-provincial knowledge absorption fund	Appropriation and absorption expenditures of industrial enterprises above designated size (ten thousand yuan)
		The concentration level of scientific research talents	Number of personnel in scientific research and technical services (persons)
	knowledge conversion	Number of new development projects	Number of new product development projects (PCS)
		Number of newly published scientific papers	New scientific and technological papers published by institutions of higher Learning and research institutes (number of articles)

4.3 Measurement Model Construction

1) Digital Economy and Regional Innovation Capability Enhancement.

In order to study the impact of digital economy on regional innovation capability, a benchmark regression model is constructed:

$$lninv_{it} = \alpha_0 + \alpha_1 lndig_{it} + \alpha_c lnR_{it} + \mu_i + \varepsilon_t + \tau_{it} \quad (1)$$

Where, inv stands for regional innovation capability, dig stands for digital economy development synergy degree, R stands for control variable set (including sch, jr,

is, rgdp, edu), α0 stands for intercept term, and α1 stands for digital economy development synergy degree coefficient. μi, εt, and τit represent fixed effects and random error terms, respectively.

2) The Influence Mechanism of Digital Economy on the Improvement of Regional Innovation Capacity.

In order to test the role of knowledge flow in promoting the coordinated development of regional innovation in digital economy, this paper draws on the intermediary mechanism test method proposed by Wen Zhonglin et al.[14], constructs the measurement model of intermediary mechanism test, and supplements the following formula (5) :

$$lnzhishi_{it} = \beta_0 + \beta_1 lndig_{it} + \beta_c lnR_{it} + \mu_i + \varepsilon_t + \tau_{it} \quad (2)$$

$$lninv_{it} = \gamma_0 + \gamma_1 lndig_{it} + \gamma_2 lnzhishi_{it} + \gamma_c lnR_{it} + \mu_i + \varepsilon_t + \tau_{it} \quad (3)$$

Where lnzhishiit represents the intermediate variable, and this paper refers to the flow of knowledge. α1 is the total effect of digital economy on the coordinated development of innovation, γ1 is the direct effect of digital economy on the coordinated development of innovation, and β1×γ2 is the intermediary effect of digital economy on the coordinated development of innovation through knowledge flow.

3) The Spatial Spillover Effect of Digital Economy.

In order to test the spillover effect of digital economy, spatial econometric model is used for analysis. Before the analysis, the global Moran index was selected for spatial correlation test.

a) Global Correlation Index (Moran's I Index).

It can be seen from the results of bivariate Moran index that there is a significant spatial positive correlation between digital economy and regional innovation ability, which preliminarily indicates that digital economy has a spatial spillover effect in the real development. The global Moran index is shown in Table 3.

Table 3. Moran's I Index of regional innovation capacity and digital economy 2011-2020

year	regional innovation capability		Degree of coordination in the development of digital economy		bivariate	
	Moran's I	*Sd(I)*	*Moran's I*	*Sd(I)*	*Moran's I*	*Sd(I)*
2011	0.485***	0.165	0.324***	0.164	0.335***	0.109
2012	0.490***	0.165	0.356***	0.165	0.399***	0.111
2013	0.508***	0.164	0.427***	0.165	0.341***	0.112
2014	0.514***	0.164	0.372***	0.164	0.379***	0.113
2015	0.548***	0.165	0.444***	0.164	0.383***	0.113
2016	0.446***	0.164	0.301***	0.161	0.355***	0.112
2017	0.416***	0.163	0.325***	0.158	0.269**	0.109
2018	0.370***	0.161	0.337***	0.157	0.248**	0.110
2019	0.357***	0.161	0.384***	0.157	0.299***	0.111
2020	0.303***	0.160	0.358***	0.155	0.270***	0.110

Note: *, **, *** indicate the significance level of 10%, 5% and 1% respectively, the same below.

5 Empirical Results and Analysis

5.1 Analysis of the Empirical Results of Digital Economy and the Improvement of Regional Innovation Capability

5.1.1 Analysis of Baseline Regression Results.

Before the empirical analysis, the variance expansion coefficient (VIF) was 3.51, significantly less than 10, and there was no multicollinearity. The baseline regression results are shown in Table 4. Columns (2) - (6) are the results of gradually adding regressive variables, and the influence results are positive, and both are significant at the level of 1%, indicating that the digital economy can significantly promote the improvement of regional innovation ability, so hypothesis 1 is confirmed.

Table 4. Analysis of benchmark regression results of digital economy and regional innovation capability improvement

variable	(1)	(2)	(3)	(4)	(5)	(6)
lndig	0.791***	0.493***	0.447***	0.371***	0.351***	0.374***
	(0.030)	(0.039)	(0.036)	(0.034)	(0.037)	(0.036)
lnsch		0.450***	0.469	0.299***	0.318***	0.294***
		(0.044)	(0.040)	(0.043)	(0.045)	(0.044)
lnjr			0.223	0.124***	0.138***	0.030
			(0.028)	(0.029)	(0.030)	(0.038)
lnrgdp				0.254***	0.280***	0.295***
				(0.033)	(0.038)	(0.037)
lnedu					-0.173	-0.399***
					(0.127)	(0.132)
lnis						0.152***
						(0.033)
cons	4.274***	3.082***	2.741***	0.334	0.357	0.879***
	(0.039)	(0.122)	(0.118)	(0.331)	(0.330)	(0.339)
Individual/time effect	control	control	control	control	control	control
N	300	300	300	300	300	300
R-squared	0.71	0.78	0.82	0.85	0.85	0.87

5.2 Robustness Test

1) Endogenous Processing.

The interaction terms between the number of fixed telephones per 100 people in each province in 2001 and the number of mobile Internet users in the previous year in the sample period were constructed as instrumental variables, and the 2SLS model was used for estimation . The empirical regression results are shown in column (1) of Table 5. The results show that after endogenous processing, the digital economy still significantly promotes the improvement of regional innovation ability.

2) Replace the Explained Variable.

The explanatory variable is replaced by the number of patent grants in this paper, and the results are shown in column (2) of Table 5.

3) Dynamic Panel Estimation.

The regional innovation capacity of the previous period may affect the current period value, so the system GMM method is used to estimate. This paper explains the reasons for meeting the condition through testing. The regression results of GMM model show that the digital economy coefficient is 0.061, which is significant at 1% level.

4) Exclude Municipalities.

The data of Beijing, Shanghai, Tianjin and Chongqing were excluded, and only samples of ordinary prefecture-level cities were retained for testing. The empirical regression results are shown in column (4) of Table 5, indicating that the digital economy still has a significant positive impact on regional innovation capability.

Table 5. Robustness test results

variable	IV_2SLS	Replace the explained variable	System GMM	Exclude municipalities
L.lninv			0.765*** (0.032)	
lndig	0.307*** (0.129)	1.812*** (0.168)	0.061*** (0.024)	0.382*** (0.041)
Individual/time effect	control	control	control	control
AR（1）			0.000	
AR（2）			0.049	
Hansen test			0.197	
Sargan- test			0.007	
K-P LM test	65.918*** (0.00)			
K-P F test	79.974*** (16.38)			
C-D F test	79.975*** (16.38)			
R-squared	0.92	0.83		0.83

Note: The Kleibergen-Paap rk LM statistic (K-P LM test) is the test of insufficient recognition of instrumental variables, and the adjoint probability is in parentheses; C-D F test (Cragg-Donald Wald F statis-tic) and K-P F test (Kleibergen-Paap Wald rk F statistic) are weak instrumental variable tests. In parentheses is the critical value for the Stock-Yogo weak instrumental variable test at the 10% significance level.

5.3 The Mediating Role of Knowledge Flow and the Causal Mediating Effect Model of Instrumental Variables

This paper theoretically analyzes how digital economy promotes the improvement of regional innovation ability through the mediating role of knowledge flow, and constructs the intermediary effect test model of stepwise regression of models (1) - (3) to

test the mediating role of knowledge flow. The empirical results are shown in Table 9. The regression results of column (2) in Table 9 show that after adding the intermediary variable of knowledge flow, the knowledge flow coefficient of the intermediary variable is 0.083, which is significant at the 1% level, indicating that the digital economy is positively driving the improvement of regional innovation ability through knowledge flow. Hypothesis 2 is confirmed.

Dippel et al.15 , introduces instrumental variables into the model and builds a causal intermediary effect model introducing instrumental variables to accurately identify the intermediary effect. The causal mediating effect model with instrumental variables is as follows:

$$M_{it} = \gamma_M^Z \times Z_{it} + \gamma_M^X \times X_{it} + \epsilon_X \tag{4}$$

$$Y_{it} = \beta_Y^X X_{it} + \beta_Y^X \hat{M} + \epsilon_Y \tag{5}$$

Where, Zit is the instrumental variable, digital economy instrumental variable in IV estimation above is adopted as the instrumental variable of this model, X represents digital economy, Y represents regional innovation capability, $\hat{M}$ in model (5) is the estimated value of β_M^X, the calculation formula is as follows:

$$X_{it} = \beta_X^Z \times Z + \epsilon_X, \quad M_{it} = \beta_M^X \times \hat{X} + \epsilon_M$$

Substituting the estimated value of β_M^X into model (5) yields model (6) :

$$Y_{it} = (\beta_Y^X + \beta_Y^M \times \beta_M^X) \times X_{it} + \beta_Y^M \epsilon_M + \epsilon_Y \tag{6}$$

Among, $\beta_Y^M \times \beta_M^X + \beta_Y^X$ is the total effect of digital economy on regional innovation ability, β_Y^X means direct effect, $\beta_Y^M \times \beta_M^X$ means indirect effects.

Column (4) in Table 6 reports the regression results of the causal mediating effect model of instrumental variables, and the results show that knowledge flow has a significant mediating effect. Specifically, the indirect effect of digital economy on the improvement of regional innovation capability is positive and passes the 1% significance test. Among them, knowledge flow can explain 54.06% of the impact of digital economy on the improvement of regional innovation capacity.

In order to identify whether knowledge flow has mediating effect, the causal mediating effect model of instrumental variables is used to avoid endogeneity problem. From the regression results of the two models, the relevant regression result coefficients all show that knowledge flow plays an intermediary role in the promotion of regional innovation ability by digital economy.

Table 6. Results of mediating effect and endogeneity test

variable	lninv	lnzhishi	lninv	lnzhishi
lndig	0.382***	1.134***	0.288***	
	(0.041)	(0.230)	(0.038)	
lnzhishi			0.083***	
			(0.010)	
direct effect				0.276***
				(0.039)

indirect effect				0.324*** (0.091)
total effec				0.600*** (0.083)
K-P LM test				40.367*** (0.00)
K-P F test				44.000*** (16.38)
C-D F test				44.000*** (16.38)
control variable	control	control	control	control
Individual/time effect	control	control	control	control
cons	0.902** (0.473)	-1.710 (2.684)	1.044*** (0.419)	
Proportion of mediating action				54.06%
N	300	300	300	
R-squared	0.83	0.70	0.87	

5.4 Empirical Analysis of Spatial Spillover Effect of Digital Economy

This paper uses the spatial Durbin model for analysis, and controls the individual effect and the time effect. The spatial Durbin model is set as follows:

$$lninv_{it} = \alpha_0 + \rho W lninv_{it} + \theta_1 W lndig_{it} + \alpha_1 lndig_{it} + \theta_k WR_{it} + \alpha_k R_{it} + \mu_i + \varepsilon_t + \tau_{it} \quad (7)$$

Where, α0 is the intercept term, ρ and θ1 are the spatial autoregressive coefficients, R is a series of control variables and W is the spatial weight matrix. If ρ>0, it indicates that the innovation capability of the region has a spillover effect on the surrounding areas, and otherwise there is a siphon effect. If θ1>0, the local digital economy can promote the innovation ability of the surrounding areas, and otherwise inhibit.

Table 7 reports the regression results under the two matrices. When the spatial spillover effect is not decomposed, the coefficients of W×lndig are both positive and very significant, indicating that the digital economy has a positive spatial spillover effect. Further, from the coefficient of spatial effect decomposition, the spatial spillover effect of the digital economy accounts for 29.1% and 67.7% of the total effect, that is, in the improvement of innovation capacity in the surrounding region, the digital economy can play at least 30% of the spatial spillover driving role, hypothesis 3 is proved..

In order to demonstrate the robustness of the results, the economic geography nested weight matrix and the second-order inverse distance matrix are replaced by the economic distance matrix and the adjacency matrix. The results are shown in columns (3) and (4) of Table 7.

Table 7. Regression results of spatial spillover effect of digital economy

variable	lninv			
	$W1$ (Economic Geography nested matrix)	$W2$ (second order inverse distance matrix)	$W3$ (Economic distance)	$W4$ (Adjacency matrix)
W×lndig	0.075*	0.181*	0.130**	0.102**
	(0.049)	(0.072)	(0.067)	(0.055)
direct effec	0.271***	0.097***	0.076***	0.046*
	(0.033)	(0.028)	(0.029)	(0.027)
Spatial spillover effect	0.110**	0.203***	0.199***	0.081*
	(0.053)	(0.073)	(0.087)	(0.047)
total effect	0.382***	0.300***	0.275***	0.127***
	(0.071)	(0.081)	(0.095)	(0.048)
Individual/time fixed control variable	fixation control	fixation control	fixation control	fixation control
ρ	0.111*	0.088	0.286***	-0.176**
	(0.069)	(0.096)	(0.087)	(0.086)
δ^2	0.010***	0.003***	0.003***	0.003***
	(0.001)	(0.000)	(0.000)	(0.000)
Log-likelihood	268.251 9	425.368 6	424.525	435.603
N	300	300	300	300
R-squared	0.52	0.38	0.36	0.59

5.5 Heterogeneity Analysis

According to Q-type cluster analysis, Chinese provinces are divided into high level and low level digital economy provinces for heterogeneity research. The results in Table 8 show that the higher the level of digital economy, the stronger the effect of innovation capability enhancement.

Table 8. Heterogeneity analysis of digital economy level

variable	lninv					
	fixed effect model		W1 (Economic geographic distance nested)		W2 (second order inverse distance matrix)	
	High-level digital economy province	Low level digital economy province	High-level digital economy province	Low level digital economy province	High-level digital economy province	Low level digital economy province
lnidg	0.650***	0.249***				
	(0.081)	(0.047)				
W×lndig			0.150**	0.073**	0.279***	0.149**
			(0.087)	(0.042)	(0.121)	(0.072)
direct effect			0.030	0.081	0.063	0.106***
			(0.066)	(0.037)	(0.063)	(0.038)

overflow effect			0.172**	0.068**	0.334***	0.138**
			(0.093)	(0.038)	(0.137)	(0.065)
total effect			0.201*	0.149***	0.397***	0.244***
			(0.123)	(0.054)	(0.156)	(0.080)
Individual/time effect	control	control	control	control	control	control
control variabl	control	control	control	control	control	control
ρ			0.194**	-0.035	0.186**	-0.048
			(0.091)	(0.072)	(0.112)	(0.102)
δ^2			0.002***	0.004***	0.002***	0.004***
			(0.000)	(0.000)	(0.000)	(0.000)
Log-likelihood			198.099 2	239.385 4	202.168 0	240.928 7
N	120	180	120	180	120	180
R-squared	0.85	0.66	0.46	0.52	0.51	0.52

6 Conclusion and Enlightenment

6.1 Research Conclusion

(1) Digital economy can significantly promote the improvement of regional innovation capacity. (2) Digital economy promotes regional innovation capacity by promoting knowledge flow. (3) Digital economy can not only promote the improvement of its own regional innovation capacity, but also have a positive spatial spillover effect on surrounding areas. Among them, the bivariate Moran test of digital economy and regional innovation ability preliminarily verified the obvious spatial correlation between the two. In addition, the results of the spatial Durbin model show that digital economy has a positive spatial spillover effect. (4) Compared with provinces with low level digital economy, provinces with high level digital economy have a stronger promotion effect on the improvement of innovation capacity of themselves and their surrounding regions.

6.2 Revelation

Based on the above conclusions, this paper puts forward policy recommendations from the following three aspects: (1) Promote the improvement of regional innovation capacity through the development of digital economy. Targeted development of a number of digital software and platforms suitable for the actual needs of regional innovation, and promote the integration of digital technologies such as big data, artificial intelligence and industrial Internet with regional innovation processes. (2) Give full play to the spatial spillover effect of the digital economy to promote the innovation capacity of the surrounding regions. The government should formulate a regional innovation collaborative development strategy, realize the cross-regional flow of innovation achievements and innovation knowledge, and effectively exert the spillover effect of digital economy development on the improvement of innovation capacity in surrounding regions. (3) Form multiple regional innovation clusters. In the cluster

area, the high-level digital economy province is positioned as the central driving province in the cluster area, and the provinces in the cluster area rely on their own innovation resources to cooperate and exchange with the central province and other provinces in the cluster area to create a knowledge exchange platform.

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