International Journal of Economics, Finance and Management Sciences
2022; 10(3): 83-91
http://www.sciencepublishinggroup.com/j/ijefm
doi: 10.11648/j.ijefm.20221003.11
ISSN: 2326-9553 (Print); ISSN: 2326-9561 (Online)

Digital Economy, R&D Innovation and Regional Integration: A Study Based on Three Chinese Urban Agglomerations

Zijian Chen[1], Yanan Sun[2, *]

[1]International Department, Jinan Foreign Language School, Jinan, China

[2]School of Economics, Ocean University of China, Qingdao, China

Email address:

13969070011@139.com (Zijian Chen), syn676897@163.com (Yanan Sun)

[*]Corresponding author

To cite this article:

Zijian Chen, Yanan Sun. Digital Economy, R&D Innovation and Regional Integration: A Study Based on Three Chinese Urban Agglomerations. *International Journal of Economics, Finance and Management Sciences*. Vol. 10, No. 3, 2022, pp. 83-91.
doi: 10.11648/j.ijefm.20221003.11

Received: April 20, 2022; **Accepted**: May 5, 2022; **Published**: May 12, 2022

Abstract: Regional integration is a major national development strategy. Whether the rapid development of digital economy can promote R&D innovation and realize regional integration is worthy of further discussion. This paper examines the relationship between digital economy, R&D innovation and regional integration by taking three urban agglomerations in China from 2011 to 2018 as research samples. Referring to the existing research, this paper constructs regional integration index and digital economy index. The regional integration index is constructed from the perspectives of economy, science and technology and ecology. The entropy method is used to comprehensively measure the digital economic index at the urban level from the two levels of Internet development and digital inclusive financial development, and the relationship between them is empirically tested. The results show that both digital economy and R&D innovation help to improve the level of regional integration. R&D innovation plays a mediating role in the mechanism of digital economy influencing regional integration, and digital economy indirectly affects regional integration through R&D innovation. Further construct the spatial Durbin model to study the spatial spillover effect between digital economy and regional integration. It is found that digital economy has an obvious spatial spillover effect on regional integration. Specifically, the digital economy promotes regional integration in the region and inhibits regional integration in adjacent regions. Based on the research results, this paper puts forward the following policy suggestions: build and improve the digital economy system, increase the intensity of innovation, improve regional integration policies, and realize the development of regional integration.

Keywords: Digital Economy, R&D Innovation, Regional Integration, Mediating Effect, Spatial Durbin Model

1. Introduction

Since the beginning of the 20th century, regional integration has emerged as a new development trend. The establishment of an integrated region can strengthen cooperation and production circulation and improve the competitive advantage of the country. Regional integration is an important measure to achieve high-quality economic development. In 2019, the State Council issued the Outline of the Development Plan of Regional Integration in the Yangtze River Delta, which raised the development of regional integration as a national strategy. The government work report of the same year pointed out that promote regional coordinated development, optimize the pattern of regional development, in particular, it puts forward clear strategic requirements and deployment for the coordinated development of the three strategic regions, namely, Beijing-Tianjin-Hebei region, the construction of Guangdong-Hong Kong-Macao Greater Bay Area and the integration development of the Yangtze River Delta. At present, China pays more and more attention to the development of regional integration. The Beijing-Tianjin-Hebei region, the Yangtze River Delta and the Pearl River Delta have developed into the regional core of China's economic development. The three urban agglomerations have strong economic strength and provide sufficient capital and human capital for economic

development. At the same time, the scale of digital economy is growing. The White Paper on China's Digital Economic Development released by China Information and Communication Research Institute shows that China's digital economy reached 39.2 trillion yuan in 2020. The efficiency growth and output increase brought by the application of digital economy have become the main engines to promote economic development. The development of China's digital economy presents obvious regional agglomeration characteristics, and the new models and new formats derived from digital economy contribute to R&D innovation, enhance exchanges and cooperation between cities, and have an important impact on regional integration. Therefore, it is important to study the impact of digital economy on regional integration for the realization of regional integration and high-quality economic development.

The research related to this paper mainly has the following two aspects. The first is regional integration. Regional integration was first proposed by Tinbergen [1], who defined regional integration as cooperation among regions to achieve optimal economic structure. Balassa [2] further pointed out that regional integration included not only measures to reduce the development gap within the region, but also the disappearance of the gap. Scott [3] summarized the content of regional integration as eliminating trade barriers and realizing the free flow of production factors. On this basis, Estrada [4] and Arturo [5] used GDRI model to construct an index system including political, economic, social and technical dimensions to measure the level of regional integration development. Shen [6] analyzed the integration level between Hong Kong and Shenzhen, and found that the region has not yet formed integration in institutional, economic and social aspects. The second is the digital economy. The digital economy is proposed by Tapscott [7], the father of the digital economy. He believes that the digital economy consists of the information and communication industry and the e-commerce part of enterprises and individuals. There are many studies on the connotation of digital economy. Scholars define digital economy from different perspectives. Early studies generally equate digital economy with e-commerce, but in addition to e-commerce, digital economy also includes information technology [8]. Kling and Lamb [9] pointed out that the digital economy includes digital products and services and the information technology industry that supports the above-mentioned commodity production. Services include electronic transfer, software sales, and remote learning [10]. The e-commerce and retail industries based on the information technology industry also belong to the category of the digital economy [11]. The three important components of the digital economy are facilities, industries and users [12]. The 2016 G20 Summit proposed that digital economy is a series of economic activities with the use of digital knowledge and information as key production factors, modern information network as an important carrier, and the effective use of information and communication technology as an important driving force for efficiency improvement and economic structure optimization. At present, different countries or organizations have formulated different evaluation systems of digital economic indicators: the European Union's digital economy and social index, the OECD's digital economic index system, the International Telecommunication Union's information and communication technology development index, the World Economic Forum's network readiness index, Eisengel's digital density index, McKinsey Unicom index, etc. By combing the existing literature, it can be found that there are few literatures on the development of digital economy and regional integration. The existing research focuses on the economic impact of digital economy, and studies the positive effect of information technology related industries on economic growth in Asia and Europe [13, 14], digital economy helps the development of inclusive finance and promotes sustainable economic development [15]. Digital economy can alleviate the information asymmetry between R&D personnel and consumers through e-commerce platform, promote collaborative innovation between R&D personnel and consumers, and promote industrial chain upgrading [16].

The shortcomings of existing research are mainly reflected in the following aspects. There are few studies on the relationship between digital economy and regional integration, but digital economy is the power of regional integration development. Promoting the deep integration of digital economy and regional integration development helps to promote high-quality economic development. There are few literatures on the path of digital economy affecting regional integration. Based on this, this paper takes Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta as the research samples, and tries to study from the following aspects: the impact of digital economy on regional integration, the role of R&D innovation in the mechanism of digital economy affecting regional integration, and whether there is spatial spillover effect of digital economy on regional integration. The marginal contribution of this paper is mainly reflected in the following three points. Firstly, the regional integration index is constructed from the perspectives of economy, science and technology and ecology. The entropy method is used to comprehensively measure the digital economic index at the urban level from the two levels of Internet development and digital inclusive financial development, and the relationship between them is empirically tested. The second is to take R&D innovation as the intermediary variable to study the specific path of digital economy to regional integration. The third is to construct the spatial Durbin model to study the spatial spillover effect of digital economy and regional integration.

2. Mechanism Analysis and Research Hypothesis

The effect of digital economy on regional integration process is mainly reflected in the aspects of economy, science and technology, ecology and so on. In terms of economy, under the rapid development of digital economy, the development of Internet of Things and intelligent technology is conducive to the realization of intelligent production and the

improvement of production efficiency of enterprises [17], that is, the increase of enterprise output and the promotion of economic development under the condition of constant cost [18]. At the same time, the outward radiation ability of economy is improved, the industrial transformation and economic development of marginal cities are faster, the economic development gap between marginal cities and central cities is narrowing, and the process of regional integration is accelerating. In terms of science and technology, the development of digital economy reduces the cost of information dissemination, and the knowledge spillover increases, which makes various new models, new products and new formats gradually emerge, and the development of science and technology advances by leaps and bounds. The scientific and technological effect of digital economy is an important driving force for improving regional strength, and it is also the main factor for realizing regional integration development. In terms of ecology, digital economy contributes to ecological environment governance, making up for the problems of manual supervision and data feedback. Under the application of digital technology, environmental pollution can be traced back to the pollution source, inhibiting the pollution emission behavior of enterprises, so that a single city cannot discharge pollution to other cities, and realize regional integration. Based on the above analysis, the following assumptions are made:

H1: Digital economy helps to achieve regional integration.

With the development of digital economy, the rise of technologies such as 5G and big data helps to promote the exchange of information among cities in the region, break the constraints of geographical space and administrative barriers, realize the free flow of innovation factors, and form a regional system of collaborative innovation. With the wide application of digital technology, the innovation level of cities has been improved [19]. The integration of traditional industries, traditional products and digital technology can develop various new models, new products and new formats, promote the application of digital technology in marginal cities to improve the scientific and technological content of products and industrial upgrading, improve the level of scientific and technological innovation of cities, and promote regional innovation integration. Innovation resources have a strong ability to dominate the value chain. Building and optimizing regional innovation systems and realizing regional collaborative innovation should become the leading and main force to promote regional integration. R&D innovation plays an intermediary role between digital economy and regional integration, and digital economy can achieve regional integration by improving R&D innovation. Based on the above analysis, this paper puts forward the following assumptions:

H2: R&D innovation helps to achieve regional integration.

H3: Digital economy promotes regional integration by improving innovation level.

Due to the spatial mobility of elements in adjacent areas, digital economy will break through the limitation of geographical distance and produce spatial spillover effects on regional integration to a greater extent. Under the background of the increasingly perfect transportation infrastructure and the rapid development of information and communication technology, the flow of knowledge, information and other factors is accelerating, the radiation range of economic activities is expanding, and the pattern of interconnection between regions is gradually formed. The spatial correlation of regional integration cannot be ignored. In addition, the development of regional integration in the region will also be affected by the economic activities of the surrounding cities. The demonstration effect makes the regions with low degree of regional integration take the initiative to imitate learning and bring spatial spillover effects. Based on the above analysis, this paper puts forward the following assumptions:

H4: The impact of digital economy on regional integration has spatial spillover effect.

3. Empirical Design

3.1. Data Source

This study selects the Beijing-Tianjin-Hebei urban agglomeration, the Yangtze River Delta urban agglomeration and the Pearl River Delta urban agglomeration for research. The Beijing-Tianjin-Hebei urban agglomeration includes 14 cities such as Beijing, the Yangtze River Delta urban agglomeration includes 26 cities such as Shanghai, and the Pearl River Delta urban agglomeration includes 9 cities such as Guangzhou. The sample period is 2011-2018. The index data selected in this paper mainly comes from China Urban Statistical Yearbook. The missing data are supplemented by interpolation method, and the variables related to currency have been reduced.

3.2. Variable Selection

In this paper, the selected variables are described as follows: (1) The explained variable is the regional integration index. Considering the processing method of existing literature and the availability of data, the per capita GDP, the number of patent authorization per capita and the ratio of GDP to industrial sulfur dioxide are selected from three aspects of economy, science and technology and ecology. The entropy method is used to construct the index to measure. (2) The explanatory variable is the digital economic index. This paper uses the entropy method to comprehensively measure the digital economic index at the city level from the two levels of Internet development and digital inclusive financial development. The Internet development dimension selects the proportion of international Internet users to the population index, and the digital inclusive finance dimension selects the digital inclusive finance index of Peking University Digital Inclusive Finance Index (II) from 2011 to 2018 at the city level. The index measures the development of digital finance from three dimensions: digital finance coverage, use depth and digital level. (3) The intermediary variable is R&D innovation index, which is measured by the ratio of government R&D expenditure to fiscal expenditure. (4) The control variables include the following four

indicators: the physical capital indicator is measured by the ratio of fixed asset investment to GDP; the human capital index is measured by the ratio of the urban college population to the total population; the urban traffic infrastructure level index is measured by per capita road area; the economic development level is measured by the average wage of labor force. In order to reduce heteroscedasticity and increase data stability, the logarithm of each variable is taken. Descriptive statistics of each variable are shown in the following table.

Table 1. *Descriptive statistics of variables.*

Variable	Symbol	Mean	Standard Deviation	Minimum	Maximum
Regional integration	lninter	1.850	1.210	-0.820	4.600
Digital economy	lnde	4.830	0.450	3.460	5.480
R&D innovation	lnrd	-3.630	0.820	-5.800	-1.350
Material capital	lninv	-0.460	0.450	-1.820	0.320
Human capital	lnedu	-3.960	0.870	-6.190	-2.060
Urban traffic infrastructure level	lntrans	2.750	0.440	1.540	4.290
economic development level	lnwage	2.390	0.0500	2.300	2.540

3.3. Model Design

In order to verify the above assumptions, this paper constructs the following econometric model.

First, in order to test hypothesis 1, that is, the relationship between digital economy and regional integration, build a model (1):

$$\mathrm{lninter} = \alpha_0 + \alpha_1 \mathrm{lnde} + \alpha_2 \mathrm{lninv} + \alpha_3 \mathrm{lnedu} + \alpha_3 \mathrm{lntrans} + \alpha_4 \mathrm{lnwage} + \varepsilon_{it} \quad (1)$$

Second, in order to test hypothesis 2, that is, the relationship between R&D innovation and regional integration, build a model (2):

$$\mathrm{lninter} = \beta_0 + \beta_1 \mathrm{lnde} + \beta_2 \mathrm{lnrd} + \beta_3 \mathrm{lninv} + \beta_4 \mathrm{lnedu} + \beta_5 \mathrm{trans} + \beta_6 \mathrm{lnwage} + \varepsilon_{it} \quad (2)$$

Third, in order to test hypothesis 3, that is, the role of R&D innovation in the impact of digital economy on regional integration mechanism, test it with reference to the intermediary effect model, and construct the model (3)-(5):

$$\mathrm{lninter} = \alpha_0 + \alpha_1 \mathrm{lnde} + \alpha_2 \mathrm{lninv} + \alpha_3 \mathrm{lnedu} + \alpha_3 \mathrm{lntrans} + \alpha_4 \mathrm{lnwage} + \varepsilon_{it} \quad (3)$$

$$\mathrm{lnrd} = \gamma_0 + \gamma_1 \mathrm{lnde} + \gamma_2 \mathrm{lninv} + \gamma_3 \mathrm{lnedu} + \gamma_3 \mathrm{lntrans} + \gamma_4 \mathrm{lnwage} + \varepsilon_{it} \quad (4)$$

$$\mathrm{lninter} = \beta_0 + \beta_1 \mathrm{lnde} + \beta_2 \mathrm{lnrd} + \beta_3 \mathrm{lninv} + \beta_4 \mathrm{lnedu} + \beta_5 \mathrm{trans} + \beta_6 \mathrm{lnwage} + \varepsilon_{it} \quad (5)$$

Fourth, in order to test hypothesis 4, that is, the spatial spillover effect of digital economy on regional integration, build a model (6):

$$\mathrm{lninter} = \mu_0 + \rho \mathrm{lninter} + \mu_1 \mathrm{lnde} + \mathrm{Wlnde}^* \theta_1 + + \mathrm{Wlnrd}^* \theta_2 + \mathrm{Wlninv}^* \theta_3 + \mathrm{Wlnedu}^* \theta_4 + \mathrm{Wlntrans}^* \theta_5 + \mathrm{Wlnwage}^* \theta_6 + \varepsilon_{it} \quad (6)$$

where, lninter represents regional integration, lnde represents digital economy, lnde^* represents spatial spillover effect of digital economy, and lnrd represents R&D innovation; ρ is spatial autocorrelation coefficient; W is a spatial weight matrix and ε_{it} is a random interference term.

4. Empirical Results and Analysis

4.1. Baseline Regression Results

Without considering R&D innovation, the relationship between digital economy and regional integration is tested. Mixed regression, fixed effect, random effect and feasible generalized least squares (FGLS) are used for regression. The results are shown in Table 2. Considering the differences and mutual influence of economic development between regions, the model is tested. The results show that there is a problem of heteroscedasticity between groups and intra-group autocorrelation, so this study chooses FGLS estimation results to analyze.

The results of the feasible generalized least squares regression in the fourth column of the table show that there is a positive correlation between digital economy and regional integration, and it passes the test at the 1% significance level. When the digital economy increases by 1%, the level of regional integration will increase by 0.9786%, which verifies H1. The development of digital economy contributes to the integration of economic, technological and ecological dimensions and promotes the process of regional integration. In terms of control variables, physical capital shows a negative correlation with regional integration, that is, when the physical capital increases. The level of regional integration decreases; human capital and the level of urban transport infrastructure construction have a significantly positive correlation with regional integration, indicating that both of them are conducive to promoting regional integration. The regression coefficient of economic development level is positive, but this result is not significant.

Table 2. *Baseline regression results.*

variable	Mixed regression model	Fixed effect model	Random effect model	Feasible generalized least square model
lnde	0.5390***	0.3493***	0.5390***	0.9786***
	(7.89)	(7.07)	(9.56)	(11.43)
lninv	-0.5406***	0.1754	-0.5406***	-1.4939***
	(-3.27)	(1.60)	(-5.18)	(-16.78)
lnedu	0.4316***	0.3309***	0.4316***	0.2854***
	(4.62)	(4.90)	(7.19)	(6.04)
lntrans	-0.0729	-0.1061*	-0.0729	0.2251**
	(-1.07)	(-1.75)	(-1.06)	(2.56)
lnwage	1.5356***	1.9294***	1.5356***	0.7028
	(3.51)	(5.40)	(3.52)	(0.95)
Constant	-2.7567**	-2.7618***	-2.7567***	-4.6911***
	(-2.15)	(-3.53)	(-2.97)	(-2.98)
Observations	392	392	392	392
Number of city	49	49	49	49

Note: * * *, * *, * respectively indicate that the results are significant at the confidence level of 1%, 5% and 10%, and the Z value of the variable estimation coefficient is in parentheses.

Table 3. *Test results of mediating effect.*

Variable	lninter	lnrd	lninter
lnde	0.9786***	0.2903***	0.7330***
	(11.43)	(2.80)	(5.98)
lnrd			0.6368***
			(12.26)
lninv	-1.4939***	-0.3376**	-1.1507***
	(-16.78)	(-2.37)	(-16.38)
lnedu	0.2854***	0.2069***	0.0624**
	(6.04)	(3.06)	(2.02)
lntrans	0.2251**	0.0793	0.2794***
	(2.56)	(1.13)	(3.19)
lnwage	0.7028	2.1318**	-0.1762
	(0.95)	(2.29)	(-0.17)
Constant	-4.6911***	-9.7531***	-0.0298
	(-2.98)	(-5.18)	(-0.01)
Observations	392	392	392
Number of city	49	49	49

Note: * * *, * *, * respectively indicate that the results are significant at the confidence level of 1%, 5% and 10%, and the Z value of the variable estimation coefficient is in parentheses.

4.2. Mediation Effect Analysis

Refer to model 3 for mediating effect test, regression results as shown in table 3. The first column in the table is the regression results of digital economy on regional integration, which is consistent with the baseline regression results. The second column is the regression results of R&D innovation on the digital economy. There is a positive correlation between the two and it is obvious at the level of 1%. For every 1% increase in the digital economy, R&D innovation increases by 0.2903%. The mechanism of digital economy promoting R&D innovation is mainly through optimizing the external innovation environment and improving the ability of enterprises to obtain external resources. Under the implementation of the national innovation-driven development strategy, the regional innovation environment is continuously optimized. The third column is the regression results of the digital economy on regional integration when the R&D innovation index is added. It can be obtained that the regression coefficient of R&D innovation on regional integration is positive and passes the 1% significance test. This verifies H2. At the same time, since the regression coefficients of digital economy and R&D innovation are both significant, it can be judged that R&D innovation plays a mediating role in the mechanism of digital economy affecting regional integration. This verifies H3 and digital economy indirectly affects regional integration through R&D innovation.

Table 4. *Regional heterogeneity test results.*

Variable	Beijing-Tianjin-Hebei	Yangtze River Delta	Pearl River Delta
lnde	0.7594***	0.9386***	0.6229***
	(11.88)	(8.28)	(17.18)
lnrd	0.2858***	0.2546***	0.9005***
	(11.10)	(3.27)	(13.96)
lninv	-1.3844***	-1.0991***	-1.2957***
	(-29.01)	(-15.25)	(-32.58)
lnedu	0.2303***	0.2239***	0.0173**
	(9.85)	(5.61)	(2.18)
lntrans	0.0332	0.2778***	0.0198
	(0.53)	(3.72)	(0.71)
lnwage	2.3407***	-3.1571***	-0.1980
	(3.68)	(-3.39)	(-0.32)
Constant	-6.6879***	5.6975***	1.8224
	(-5.15)	(3.02)	(1.19)
Observations	112	208	72
Number of city	14	26	9

Note: * * *, * *, * respectively indicate that the results are significant at the confidence level of 1%, 5% and 10%, and the Z value of the variable estimation coefficient is in parentheses.

4.3. Regional Heterogeneity Test

The urban agglomerations are divided into Beijing-Tianjin-Hebei, Yangtze River Delta and Pearl River Delta urban agglomerations, and the above urban agglomerations are regressed to obtain the results in the table. The effect of digital economy on regional integration can be found: Yangtze River Delta > Beijing-Tianjin-Hebei > Pearl River Delta; the effect of R&D innovation on regional integration is as follows: Pearl River Delta > Yangtze River Delta > Beijing-Tianjin-Hebei. Due to the differences in

economic development level and resource endowment conditions, the effect varies in different regions. Overall, the regression coefficients of digital economy and R&D innovation to regional integration are both positive and at the level of 1%, which are consistent with the regression results of the total sample in the previous text and re-validate H1 and H2.

4.4. Spatial Spillover Effect Test

4.4.1. Spatial Autocorrelation Test

In this paper, the inverse distance weight matrix is constructed for global spatial correlation test and local spatial correlation test. In the global spatial correlation test, the Moran index is used to test the regional integration, and the results are shown in table 5. It can be concluded that the Moran index of regional integration in 2011-2018 is positive, and at the level of 1%, it shows that the regional integration of urban agglomerations in China has a significant positive correlation. In the local autocorrelation test, the scatter plots of local Moran index in 2015 and 2018 are drawn respectively (Figure 1). It can be obtained that most cities are located in the first and third quadrants, showing the characteristics of high-high agglomeration and low-low agglomeration. It again shows that there is a positive spatial correlation in the regional integration of each city, and it is appropriate to use the spatial econometric model for regression.

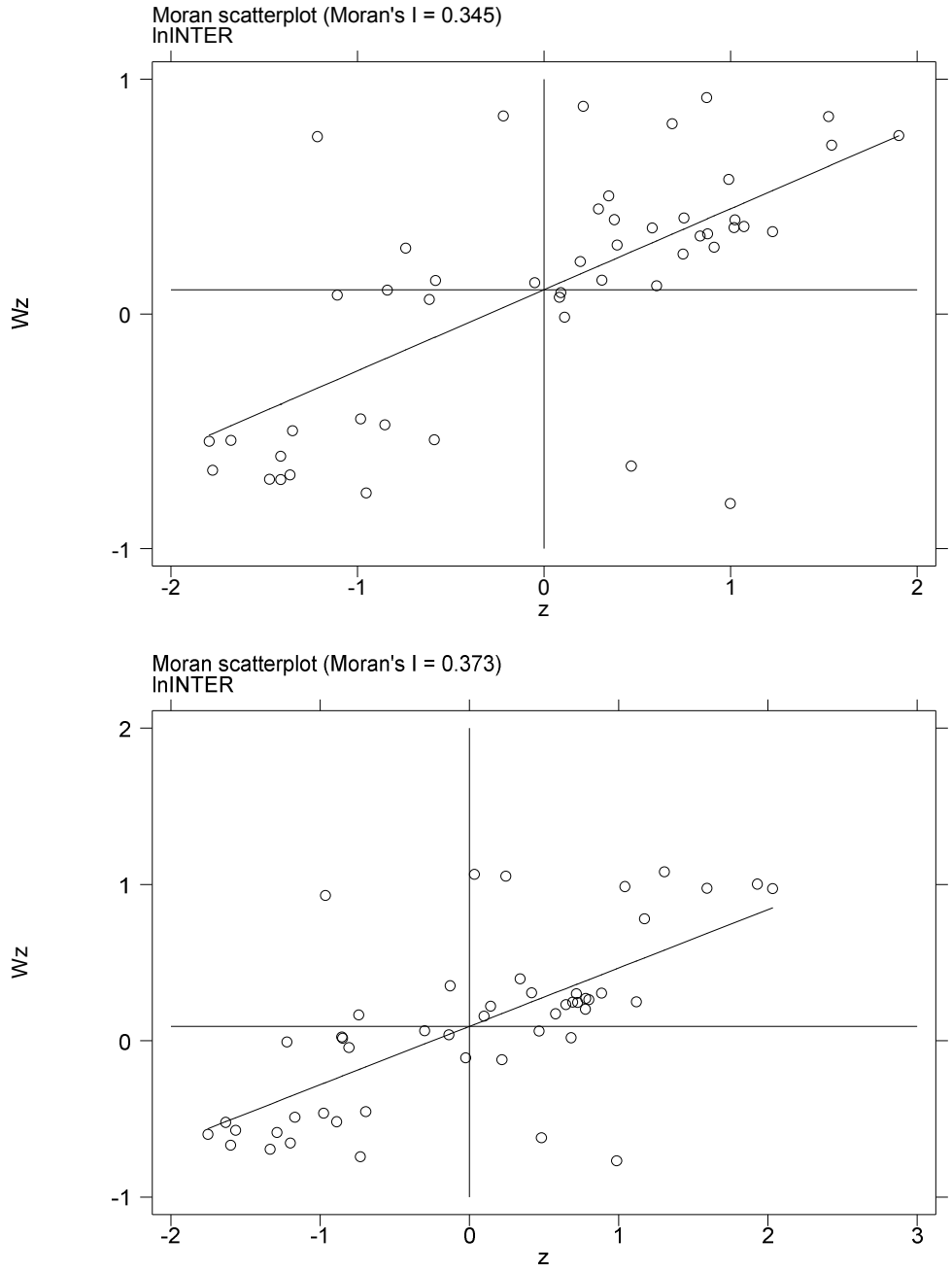

Figure 1. *Local Moran Index scatter diagram for regional integration in 2015 and 2018.*

Table 5. *Global Moran Index test results of regional integration.*

Year	Moran's I	P value
2011	0.340	0.000
2012	0.338	0.000
2013	0.344	0.000
2014	0.360	0.000
2015	0.345	0.000
2016	0.344	0.000
2017	0.358	0.000
2018	0.373	0.000

4.4.2. Model Applicability Test

First of all, before selecting a specific spatial panel model, it is necessary to determine whether the panel data use a fixed effect or a random effect. The p value of the Hausman test is 0.00, and the explicit rejects the original hypothesis, that is, the fixed effect model should be used. Secondly, LM test is used to confirm the necessity of the application of spatial econometric model again. As can be seen from Table 6, LM, robust LM and LM of the spatial lag model all pass the significant test, which again confirms the spatial correlation of the explained variables and needs to introduce the spatial econometric model. Finally, the specific form of spatial panel model is determined by Wald and LR test. It can be found from table 6 that the test rejected the original hypothesis at 1% level, indicating that the SDM model cannot be simplified as SLM and SEM models. Therefore, this paper selects the spatial Durbin model under the fixed effect for empirical test.

Table 6. *Spatial Durbin model test results.*

Test	statistical value	P value
Hausman	52.49	0.000
LM-lag	148.607	0.000
Robust LM-lag	57.778	0.000
LM-error	238.327	0.000
Robust LM-error	147.498	0.000
Wald test spatial lag model	11.02	0.0876
Wald test spatial error model	10.95	0.0898
LM test space lag model	55.12	0.000
LM test space error model	56.93	0.000

4.4.3. Regression Analysis of Spatial Econometric Model

The relationship between digital economy and regional integration is verified by three fixed effects of SDM model, and the specific regression results are shown in table 7. From the test results of the three types of effects, the spatial fixed effect is better than the time fixed effect and the double fixed effect in terms of the dominance of explanatory variables and the goodness of model fitting. In terms of economic significance, the geographical factors of the explained variable are more obvious than the time and other factors, so the spatial fixed effect is more in line with the hypothesis of this study. Therefore, this paper chooses spatial fixed effect model for empirical research.

The results in the table show that the spatial lag coefficient reflecting whether there is spatial effect of regional integration is 0.4119, which is significant at the level of 1%, indicating that there is strong spatial correlation in the development of regional integration, and the spatial spillover effect of regional integration is significant. The estimated coefficient of digital economy is 0.7839 and passes the significance level test of 1%, which shows that digital economy has a positive effect on local regional integration. The regression coefficient of spatial lag term of digital economy is -0.5670 and passes the significance test of 1%, indicating that the development of digital economy in this region inhibits the process of regional integration in surrounding areas, and the negative spatial spillover effect is obvious.

Table 7. *Spatial Durbin model test results.*

Variable	time fixed effect	spatial fixed effect	double fixed effect model
lnde	3.4181***	0.7839***	0.8716***
	(0.00)	(0.00)	(0.00)
lnrd	0.5309***	0.1250***	0.1445***
	(0.00)	(0.00)	(0.00)
lninv	-0.7353***	0.1786*	0.1349
	(0.00)	(0.06)	(0.19)
lnedu	0.0487	0.2681***	0.2884***
	(0.14)	(0.00)	(0.00)
lntrans	0.3303***	-0.1671***	-0.1319**
	(0.00)	(0.00)	(0.01)
lnwage	-2.3155	-2.1697	-3.4952**
	(0.21)	(0.20)	(0.05)
W·lnde	-2.0295	-0.5670***	1.0668
	(0.12)	(0.00)	(0.23)
W·lnrd	0.2452	-0.3249	0.0456
	(0.45)	(0.10)	(0.88)
W·lninv	-0.3484	-0.3057	-0.4432
	(0.32)	(0.37)	(0.44)
W·lnedu	2.1075***	0.6039*	1.0019***
	(0.00)	(0.06)	(0.01)
W·lntrans	-0.2442	0.0195	0.4229
	(0.49)	(0.93)	(0.13)
W·lnwage	-19.5224*	3.5670**	-9.1269
	(0.10)	(0.05)	(0.26)
rho	-0.6316***	0.4119***	-0.0705
	(0.00)	(0.00)	(0.68)
sigma2_e	0.1565***	0.0307***	0.0289***
	(0.00)	(0.00)	(0.00)
Observations	392	392	392
Number of city	49	49	49

4.4.4. Decomposition of Spatial Spillover Effect

In order to reflect the spatial spillover effect of independent variables on dependent variables more accurately, this paper further uses the partial differential method based on SDM proposed by LeSage [20] to decompose the spillover effect, and the total effect is divided into two parts: direct effect and indirect effect. The direct effect represents the impact of the development of digital economy on regional integration in the region; the indirect effect indicates the impact of digital economic development on regional integration in adjacent areas. The specific results are shown in Table 8.

Table 8. *Effect decomposition results of spatial Durbin model.*

Variable	LR_Direct	LR_Indirect	LR_Total
lnde	0.7820***	-0.4250*	0.3570*
	(0.00)	(0.07)	(0.05)
lnrd	0.1143***	-0.4629	-0.3486
	(0.00)	(0.13)	(0.27)
lninv	0.1812*	-0.3468	-0.1657
	(0.05)	(0.56)	(0.79)
lnedu	0.2912***	1.1738**	1.4650***
	(0.00)	(0.03)	(0.01)
lntrans	-0.1671***	-0.0724	-0.2395
	(0.00)	(0.86)	(0.58)
lnwage	-2.0082	4.4272**	2.4190**
	(0.22)	(0.01)	(0.02)
Observations	392	392	392
Number of city	49	49	49

It can be seen from table 8, the total effect of digital economy is 0.3570, which is divided into two parts: first, the direct effect of digital economy is 0.7820, which is significant at the level of 5%, that is, for every 1% increase in the development of digital economy in this region, the level of regional integration in this region will increase by 0.7820%; Second, the indirect effect of digital economy is -0.4250, which is significant at the level of 10%, that is, for every 1% increase in the development of digital economy in this region, the level of regional integration in adjacent regions decreases by 0.4250%. The development of digital economy has a significant spatial spillover effect on the level of regional integration.

5. Conclusions and Suggestions

This paper examines the relationship among digital economy, R&D innovation and regional integration by taking three urban agglomerations in China from 2011 to 2018 as research samples. The results show that both digital economy and R&D innovation help to improve the level of regional integration. R&D innovation plays an intermediary role in the mechanism of digital economy affecting regional integration, and digital economy indirectly affects regional integration through R&D innovation. Digital economy has an obvious spatial spillover effect on regional integration. Specifically, the digital economy promotes regional integration in the region and inhibits regional integration in adjacent regions.

Based on the above research results, this paper puts forward the following policy suggestions. First, build and improve the digital economy system, vigorously promote digital finance. Digital finance should continue to adhere to the principle of inclusive, increase the public's use of digital finance, and improve the availability of core digital financial products such as credit and insurance. Gradually establish a sound inclusive financial service system, establish more high-quality digital financial service institutions and platforms, and improve the quality and efficiency of financial services. At the same time, strengthen the boosting role of the government, improve the digital financial infrastructure, increase its convenience and improve the efficiency of financial resource allocation; we should simplify the procedures and links of digital inclusive financial services for the real economy, and give full play to the intermediary role of R&D innovation. Second, increase the intensity of innovation: pay attention to the importance of scientific and technological innovation ability to the high-quality development level of the real economy. On the one hand, the government should improve the patent application, examination, authorization and protection mechanism, and actively encourage innovation subjects to produce high-quality patents. While increasing R&D investment, innovation subjects and the government should combine environmental and objective factors to ensure the rationality of R&D investment structure, and give full play to the intermediary role of R&D investment in the impact mechanism of digital economy on regional integration. On the other hand, we should improve the transformation efficiency from R&D investment to innovation performance, speed up the transformation of scientific and technological achievements, and speed up the formation of the promotion mechanism of R&D innovation to regional integration. Third, improve regional integration policies. Promoting regional integration needs to play the role of the government. The intervention of local governments has a great impact on the integration. Eliminating the negative role of the government and playing a positive role is of great significance to the development of regional integration. Local governments should establish a sense of integration, give full play to the advantages of perfect infrastructure and active capital flow in the core area, give full play to the radiation and driving role of developed areas, and realize regional integration.

References

[1] Tinbergen J. International Economic Cooperatio [M]. the Netherlands: 1954.

[2] Balassa B. The Theory of Economic Intergration [J]. Kyklos. 1961, 1 (14): 1-17.

[3] Scott A J. World development report 2009: reshaping economic geography [J]. Journal of economic geography. 2008, 100 (35): 583-586.

[4] Estrada R. Global Dimension of Regional Integration (GDRI) Model [J]. FEA Working Paper. 2004, 7 (40): 218-234.

[5] Arturo. The global dimension of the regional intergration model (gdri-model) [J]. Modern Economy. 2013, 5 (4): 346-369.

[6] Shen J. Not quite a twin city: cross-boundary integration in HongKong and ShenZhen [J]. Habitat International. 2014, 5 (4): 138-146.

[7] Tapscott D. The Digital Economy: Promise and Peril In The Age of Networked Intelligence [M]. New York: McGraw Hill, 1996: 2-8.

[8] Brent R. Moulton, "GDP and the Digital Economy: Keeping up with the Changes" [J] Understanding the Digital Economy Data, 1999, 4 (5): 34-48.

[9] Kling R, Lamb R. IT and organizational change in digital economies [J]. ACM SIGCAS Computers and Society, 1999, 29 (3): 17-25.

[10] Haltiwanger, J dan Jarmin, R. S. Measuring the Digital Economy [M]. MIT Press Cambridge, 2000, 13-33.

[11] Moulton B R. "The system of national accounts for the new economy: What should change?", Review of Income & Wealth, 2010, 50 (2): 261-278.

[12] Naciones Unidas Comisión Económica para América Latina y el Caribe (CEPAL). The digital economy for structural change and equality [M]. Libros Y Documentos Institucionales, 2013.

[13] André H, Claudio A, Vianka A. Information And communication technologies and their impact in the economic growth of Latin America 1990-2013 [J]. Telecommunications Policy. 2016 (40): 485-501.

[14] Abdul A, Deb K. Information And communication technology and economic Growth In India [J]. Telecommunications Policy, 2016 (40): 412-431.

[15] Kapoor A. Financial inclusion and the future of the Indian e-conomy [J]. Futures, 2013 (10): 35-42.

[16] Pee LG. Customer co-creation in B2C e-commerce: does it lead to better new products? [J]. Electronic Commerce Research, 2016, 16 (2): 1-27.

[17] Ketteni E. Information Technology and Economic Performance in U.S Industries [J]. The Canadian Journal of Economics, 2009, 42 (3).

[18] Thompson P, Williamsb R, Thomas B. Are UK SMEs with active web sites more likely to achieve both innovation and growth? [J]. Journal of Small Business & Enterprise Developemnt, 2014, 20 (4): 934-965.

[19] Akcigit U, Caicedo S, Miguelez E, et al. Dancing with the Stars: Innovation through Interactions [R]. CEPR Discussion Papers, 2018.

[20] Lesage J P, Pace R K, 2009. Introduction to spatial econometrics [M]. Boca Raton: CRC Press.