Trade Openness, Digital Economy and Spatial Spillover

---An empirical study based on China's provincial panel data

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Abstract. Based on panel data of 31 provinces in China from year 2010 to 2020, this paper constructs a provincial digital economy evaluation index system to measure the digital economy development. Under the framework of static and dynamic spatial panel models, this paper empirically studies the spatial effects of China's provincial trade openness on the development of digital economy. The results show that China's provincial trade openness has obvious positive and spatial effects on the development of digital economy, and the local trade openness has a sustainable driving effect on its own digital development, but not sustainable for the neighboring region. Moreover, the influence of the eastern regional trade openness on the digital economy shows a spatial diffusion pattern in the short and long term, while that of the central and western regions shows a spatial siphon effect pattern.

Keywords: trade openness; digital economy; dynamic spatial panel; spatial effects.

1. Introduction

Since 2020, the global outbreak of the Covid-19 pandemic has brought obvious difficulties to China’s external circulation. At the same time, the development of traditional industries is also facing the need of transformation due to the slowing down of domestic economic growth. Under such circumstances, China proposed the “new development pattern” which means dual circulation of economy at domestic and abroad. The construction of China's dual circulation cannot be separated from a new factor: the digital technology. On one hand, the rapid development of digital economy will greatly promote the domestic circulation, expand supply, stimulate market demand and drive consumption. New production and industries brought about by the digital economy have injected new impetus into the domestic circulation. On the other hand, the new development pattern also attaches great importance to the role of external circulation, expecting to promote high-quality internal circulation through high-level external circulation.

In this regard, China will further expand trade liberalization, actively cooperate with foreign countries, and better integrate domestic economic development into the international division of labor. Therefore, it is of great practical significance for this paper to examine the impact of China's external circulation activity of continuously increasing opening-up through foreign trade on the development of China's digital economy, analyze the different characteristics of this impact in different regions, and fully consider the impact of spatial spillover effect.

However, the current literature shows the following deficiencies. First of all, existing literature either only analyzes the impact of digital economy on trade, or only takes trade as one of the factors affecting the development of digital economy, and fails to fully recognize the significance of the impact of trade openness on the development of digital economy under the new development paradigm, so there is a lack of systematic and in-depth specialized analysis. Secondly, in previous studies, although the factors affecting the development of digital economy have been analyzed in a certain space, they are static, and the dynamic change process of digital economy and its related elements has not been included in the study. Thus, this paper will establish static and dynamic spatial panel models to specific ally explore the impact of China's provincial trade openness on digital economy, and pay attention to the long-term and short-term differences, spatial spillover effects and regional heterogeneity. This is of great significance for grasping the opportunities of the new wave of technological revolution and industrial transformation, improving the level of China's trade openness and digital economy development, and promoting the establishment of a new development paradigm.

2. Measurement and Evaluation of Development Level of Digital Economy

The specific indicators of a comprehensive index system are shown in Table 1. The data are mainly from the National Bureau of Statistics, the Ministry of Industry and Information Technology, etc.

Table 1. Index system of digital economy

First-level indicators	Secondary indicators	Tertiary indicators
Digital infastructure	Information-based infastructure	Optical cable density (km/'sq km)
		Density of mobile phone base stations (PCS/km2)
	Fundamentals of the Intemet	Percentage of Mobile Internet users (percent)
		Density of Intemet access ports (PCS/person)
		Mobile phone penetration (percent)
Industry digitization	Digital agriculture	Per capita rural electricity consumption(billion KWH/10,000 people)
		Proportion of total output value of agriculture，restry，animal husbandry and fshery (percentage)
	Digital industry	Proportion of R&D personnel in industrial enterprises above designated size (percentage)
		Proportion of R&D expenditure of industrial enterprises above designated size (percentage)
	Digital tertiary industry	Per capita consumption of culture,education and entertainment (percentage)
		Per capita spending on transportation and communications(percent)
	Digital transactions	Per capita e-commerce sales (100 million yuan)
		Proportion of e-commerce transaction activity (percentage)
Digital industrialization	Development benefts of digital in dustrialization	Per capita income of express business (ten thousand Yuan)
		Per capita income from infrmation technology services (100 million yuan)
		Per capita revenue fom sofware business (100 million yuan)
	The development scale of digital industrialization	Proportion of employment in postal industry (percentage)
		Total postal business per capita (100 million Yuan)
		Total telecom business per capita (100 million yuan)
		Percentage of employment in sofware and infmation technology services (percent)
		Percentage of employment in Intemet and related services (percent)

The paper uses the improved entropy method to give a weighted and comprehensive score to each index of digital economy. On the basis of the overall change effect based on the data, the improved entropy method fully considers the interaction of panel data in time and space without being affected by subjective factors and subjective factors. Due to the space limitation, the calculation process is omitted, and the final measurement results are shown in Table 2.

According to the classification standard of the National Bureau of Statistics, China's 31 provinces are subdivided into three regions: eastern, central and western regions. As can be seen from Table 2, there are spatial differences in the development level of digital economy among different regions in China. The overall development level of the eastern region is higher than that of the central and western regions, while the central and western regions are similar. From the time change point of view, since 2010, the development of digital economy in all areas of China has been on the rise.

Table 2. Average score of digital economy level

Year/Region	Eastern region	Central region	Western region
2010	0.611	0.113	0.115
2011	0.624	0.103	0.110
2012	0.622	0.108	0.117
2013	0.609	0.113	0.125
2014	0.610	0.110	0.129
2015	0.652	0.120	0.136
2016	0.631	0.120	0.134
2017	0.689	0.150	0.148
2018	0.705	0.138	0.148
2019	0.713	0.143	0.152
2020	0.784	0.164	0.163

3. Study Design

3.1 Spatial Weight Matrix

To construct the corresponding spatial analysis model, it is necessary to discuss the influence of geographical characteristics on spatial relations, that is, to determine the appropriate spatial weight matrix. On this basis, the paper chooses two different spatial models.

First, geographic adjacency matrix. This method has been widely used in the spatial analysis of regional economy, that is, when two provinces are adjacent to each other and its assignment is 1 instead of the neighboring province, then it is 0. The spatial matrix W1 of 31 provinces can be obtained. The specific formula is as follows:

$$Wij = \begin{cases} 0, & (i = j) \\ 1, & (i \neq j) \end{cases} \tag{1}$$

Second, geographical distance matrix. Considering that even if two provinces are not adjacent but have the same or similar economic characteristics, there will be spatial correlation, which will also lead to spatial spillover effect of digital economy and trade quality. Therefore, the geographical distance matrix W2 is established here. The specific formula is as follows:

$$Wij = \begin{cases} 1/d, & (i \neq j) \\ 0, & (i = j) \end{cases} \quad (2)$$

3.2 Spatial Correlation Test

Before selecting a model, it is necessary to conduct a spatial correlation test to judge the suitability of a spatial metrological model in this paper, the spatial autocorrelation test is conducted for the digital economy level of 31 Chinese provinces.

The test results show that in the two matrices, Moran's I value of each year is positive, and through the significance test, as shown in Table 3, the development of digital economy in 31 provinces of China has agglomeration effect, and the development of digital economy can exert the spatial spillover effect to a certain extent, and promote the development of digital economy in the surrounding areas.

Table 3. Results of Moran's I

Year	W1			W2		
	I	Z	P-value	I	Z	P-value
2010	0.117	1.774	0.038	0.009	1.720	0.043
2011	0.117	1.814	0.035	0.008	1.734	0.041
2012	0.131	1.939	0.026	0.011	1.798	0.036
2013	0.169	2.095	0.018	0.021	1.945	0.026
2014	0.173	2.118	0.017	0.020	1.922	0.027
2015	0.200	2.346	0.009	0.014	1.712	0.043
2016	0.174	2.160	0.015	0.016	1.769	0.038
2017	0.208	2.264	0.012	0.003	1.317	0.094
2018	0.253	2.892	0.002	0.021	1.949	0.026
2019	0.231	2.614	0.004	0.008	1.518	0.065
2020	0.144	1.811	0.035	0.013	1.639	0.051

3.3 Choice of Spatial Panel Mode1

The next is the selection of spatial models. Currently, the commonly used spatial models include spatial Durbin model (SDM), spatial lag model (SAR) and spatial error model (SEM). First of all, LM test is used to judge these three methods. Generally, the applicability of SAR and SEM models can be judged. The LM results show that both models are suitable. Secondly, LR test and Wald test are used to verify whether the SDM model degenerates into SAR and SEM models. Finally, Hausman test is used to verify that the fixed effect is more suitable. Therefore, the SDM model is set as follows:

$$yit= \rho\ Wiyt+ \beta\ 0openit+ \beta\ 1controlit+ \beta\ 2Wiopent+ \beta\ 3Wicontrolit+ \mu\ i+ \gamma\ t+ \varepsilon\ it \quad (3)$$

Where, y is the development level of digital economy; open is openness level; control is control variable; $\beta0$-$\beta3$ are the parameter to be estimated; ρ is the spatial autoregressive coefficient; W is the spatial weight matrix; μi And γt are control individual and time fixed effect respectively; εit is the error term; i is province; t is year.

Given that the development of regional digital economy is dynamic, the level of the previous period may have a certain impact on the development of the current period. Therefore, the dynamic spatial panel model is also established in this paper:

$$y_{it} = Ty_{i,t-1} + \rho W_i y_t + \beta_0 open_{it} + \beta_1 control_{it} + \beta_2 W_i open_{it} + \beta_3 W_i control_{it} + \mu_i + \gamma_t + \varepsilon_{it} \quad (4)$$

Where, T is the time lag coefficient; yi,t-1 is one period of lag of the explained variable, ρ is the spatial autoregressive coefficient.

3.4 Variable Selection

In the static spatial model formula (3) and dynamic spatial model formula (4), the explained variable is the digital economy development level (y) of China's provinces, which is calculated from the above. The key explanatory variable is trade openness, measured by the ratio of import and export to GDP of each province.

The control variables (control) adopted by the model include economic development level (pgdp), government expenditure (gov) and urbanization level (urb). The economic development level (pgdp) selects per capita GDP as the measurement index. Government expenditure (gov) is measured by the proportion of government fiscal expenditure in GDP. The level of urbanization (urb) is expressed by the proportion of urban population to total population.

The paper uses data from year 2010 to 2020, covering 31 provinces and cities in China. All the data are from the National Research network statistical database. The related price data were all treated with constant price, with 2010 as the base year.

4. Empirical analysis

4.1 Analysis of Spatial Model Regression Results

In Table 4, models (1) and (3) are the static SDM model regression results, and models (2) and (4) are the dynamic SDM model regression results.

By comparing the static and dynamic SDM models under different spatial matrices, it is found that there are slight differences in the coefficient. For example, under the geographical adjacency matrix, the coefficient of trade openness is 0.149 in the static model, while it is 0.0033 in the dynamic model This difference is because the traditional static model assumes that the digital economy has no self-dynamic adjustment process, and the development of the digital economy is often with path dependence, so the effect of the dynamic model is better than that of the static model. Therefore. this paper focuses on the analysis of dynamic model regression results.

According to the dynamic spatial model (2) and (4), under the two matrices, the coefficient of digital economy lagging one phase is significantly positive, which indicates that the digital economy level of the current year will be affected by the development of digital economy in previous years, and there is a certain time dependent effect. At the same time, ρ coefficient is also significantly positive, which indicates that digital economy has spatial spillover effect, that is, when the level of digital economy in a province improves, it will promote the development of digital economy in the surrounding regions, and this spatial effect still exists, so the setting of dynamic model is reasonable.

In all models, the trade openness in the province has a significant promoting effect on the digital economy in the province, and also has a positive spatial spillover effect on the development of digital economy in the neighboring regions. It can be seen that, with the continuous enhancement of inter-provincial factor flow and the improvement of inter-provincial trade openness, various dividends generated will be transformed to the development of digital economy inside and outside the region.

In spatial regression analysis, regression results without effect decomposition may produce corresponding errors. The above results can be used as preliminary judgment. Next, the paper draws on partial differential method from Lesage et al[10], based on the W2 matrix SDM panel model, divides it into direct effects and indirect effects to get the results in Table 5.

Table 4. SDM regression results

Variables	W1		W2	
	Model(1)	Model(2)	Model(3)	Model(4)
l.y		1.067***(0.011)		1.171***(0.010)
open	0.035***(0.010)	0.003*(0.002)	0.034***(0.007)	0.008***(0.003)
pgdp	0.012***(0.001)	-0.000(0.000)	0.013***(0.001)	-0.001***(0.000)
urb	0.0009***(0.000)	0.000*(0.000)	0.0009***(0.000)	0.000***(0.000)
gov	0.000***(0.000)	-0.0001***(0.000)	0.000***(0.000)	0.000(0.000)
Wopen	-0.655***(0.072)	-0.0030(0.003)	-2.819***(0.166)	0.027(0.030)
Wpgdp	0.001***(0.000)	-0.001*(0.001)	0.000***(0.000)	-0.024***(0.005)
Wurb	0.0339**(0.013)	0.000(0.000)	0.149***(0.050)	-0.0054***(0.001)
Wgov	0.011***(0.003)	0.000(0.000)	0.049***(0.007)	0.000*(0.000)
ρ	-0.001(0.001)	0.065***(0.022)	-0.001(0.001)	3.7330***(0.260)
sigma2_e	0.000***(0.000)	0.000***(0.000)	0.000***(0.000)	0.000***(0.000)
R2	0.654	0.989	0.731	0.929

Note: Standard error values in brackets: *, **, and***represent significant at the level of 10%, 5% and 1% respectively, as below.

The results of Table 5 show that, firstly, the total effect of trade openness on the digital economy is significantly positive in both the short and long run, indicating that trade openness has a significant role in promoting the development level of the digital economy in the whole region and will continue to do so. In other words, an increase in the level of trade openness will promote the level of development of the digital economy.

Secondly, from the perspective of direct effect, both short-term and long-term direct effects of trade openness on digital economy are significantly positive. The improvement of trade openness level will promote the development of local digital economy. This is mainly due to the improvement of the region's trade openness, which enhances the horizontal flow, drives the spatial agglomeration of various industries, and thus promotes the development of digital economy in this province. In addition, comparing the short-term and long-term results, it is found that the direct effect coefficient of long-term trade openness is greater than that of short-term direct effect, indicating that the positive impact of trade openness on regional digital economy has a continuous continuity, and the positive impact of trade openness will be greater as time goes by.

Thirdly, from the perspective of indirect effect, trade openness has a significantly positive impact on the development of digital economy in surrounding provinces in the short term. When the level of trade openness of this province is improved, it will have a positive impact on the digital economy construction of surrounding provinces and promote the digital construction of surrounding areas. In the long run, the indirect effect is negative but insignificant. It can be seen that the impact of trade openness on the digital economy of surrounding provinces may show an inverted U-shaped structure that first increases and then decreases. The long-term improvement of trade openness may have a negative impact on the digital economy development of surrounding provinces.

Table 5. Dynamic SDM decomposition results

Variables	**open**	**pgdp**	**urb**	**gov**
Short-term direct effects	0.042***(0.010)	0.013***(0.001)	0.001***(0.000)	0.000***(0.000)
Short-term indirect effects	0.044***(0.016)	0.014***(0.0037)	0.000(0.0004)	0.000***(0.000)
Short-term total effects	0.086***(0.017)	0.027***(0.004)	0.001(0.000)	0.000***(0.000)

Long-term direct effects	0.045***(0.016)	0.014***(0.002)	0.001**(0.001)	0.000***(0.000)
Long-term indirect effects	0.005(0.017)	0.001(0.003)	0.000(0.001)	0.000(0.000)
Long-term total effects	0.034***(0.006)	0.013***(0.001)	0.000(0.000)	0.000***(0.000)

4.2 Regional Heterogeneity Analysis

Considering that there may be regional differences in the impact of trade openness on the development of digital economy, this paper continues to explore the spatial impact of trade openness on the development of digital economy by region. Due to space limitation, only the analysis results of the core explanatory variable(open) based on SDM model are presented here. as shown in Table 6.

In the short term, from the perspective of direct effect, trade openness of the three regions has a significantly positive impact on the development of digital economy, among which the central region has the greatest impact, followed by the western region and the eastern region. According to the above calculation results of digital economy, the growth rate of digital economy development in the eastern region is lower than that in the central and western regions. Therefore, the impact of trade openness on digital economy is weaker in the eastern region than in the central and western regions. From the perspective of indirect effect, the eastern region is significantly positive and has the largest value in the short term, while the central region becomes the weakest, indicating that the impact of the level of trade openness in the eastern region on the digital economy has a strong spatial spillover effect compared with other regions. For the eastern region, trade activities are especially frequent. The broad field market and the consequent competitive pressure promote the agglomeration of relevant industries in the eastern region, which makes the application and diffusion effect of digital technology more obvious and the development of regional digital economy more dynamic. The short-term indirect effect in the central region is significantly negative, which may be the reason that the improvement of the level of local trade openness will attract foreign digital industries to invest in the local region, and the impact on the development of digital economy in the foreign region is limited or even negative. However, it is not significant in the western region, which may be because the impact of trade openness in the western region is limited and will not affect the development of digital economy in the surrounding areas in the short term. As a result, in terms of the overall effect, the short-term effect in the eastern region is the most prominent, followed by the central region and the western region, showing a gradient differentiation pattern of "east, central and west."

In the long run, the order of the direct effect of the three regions is consistent with the short run effect, with the central region having the largest direct effect, followed by the western region, and the eastern region having the weakest direct effect. Similarly, in the indirect effect, the coefficient of the central and western regions is significantly negative. That means, for a long time, the impact of the trade openness in the central and western regions on the digital economy of the surrounding regions has not been positive, but promoted the digital economy of its region. This shows that the longer the time, the weaker the spatial effect of the trade openness in the central and western regions on the digital economy, and the stronger the siphon effect. Therefore, in terms of the total effect, the eastern region once again catches up and forms the gradient differentiation pattern of "east, central and west" again.

Table 6. Effect decomposition by region

	Type of effects	Eastern region	Central region	Western region
Open	Short-tern direct effects	0.011***(0.003)	0.022***(0.006)	0.019*(0.010)
	Short-tern indirect effects	0.002**(0.001)	-0.012***(0.004)	0.001(0.008)

	Short-tern total effects	0.013***(0.004)	0.010***(0.003)	0.020(0.013)
	Long-tern direct effects	-0.167(0.168)	0.038***(0.013)	0.027*(0.014)
	Long-tern indirect effects	0.1200(0.1660)	-0.026**(0.012)	-0.021*(0.011)
	Long-tern total effects	-0.047***(0.018)	0.011***(0.004)	0.006*(0.003)

4.3 Robustness Test

Based on the economic gap of each province, the spatial econometric estimation is re-conducted by using the economic geographical spatial weight matrix to test the stability of the regression results. The specific formula is:

$$W_3 = W_2 \times E \tag{5}$$

$$E = \frac{\sum_{i=1}^{n} y_{it} / n}{\sum_{i=1}^{n}\sum_{i=1}^{n} y_{it} / nt}$$

In which, .

Since the weights were changed, the model selection test for the new weights was carried out, and the results showed that the SDM model should continue to be used for the test. Table 7 shows the SDM model in the economic geospatial weight matrix (W3). It can be seen that under the time-fixed effect model, the sign and significance degree of the estimation coefficient do not change significantly, and the results are stable.

Table 7. replaces the results of explanatory variables

	Time fixed effect	Individual fixed effect	Double fixation effect
l.y	1.006***(0.010)	0.654***(0.052)	0.625***(0.051)
open	0.013***(0.002)	0.007*(0.004)	0.003(0.004)
Wopen	0.150**(0.063)	-0.005(0.028)	-0.012(0.145)
ρ	14.770***(0.343)	0.114(0.261)	2.768***(0.955)
sigma2_e	0.000***(0.000)	0.000***(0.000)	0.000***(0.000)
control variable	control	control	control
R2	0.962	0.954	0.945
LM-Spatial lag	2.767 *		
Robust LM-Spatial lag	40.049***		
LM-Spatial error	6.216**		
Robust LM-Spatial error	43.498***		
LR-Spatial lag	34.100***		
LR-Spatial error	48.440***		

5. Conclusions and Recommendations

Based on the panel data of 31 provinces in China from 2010 to 2020, this paper constructs the provincial digital economy level evaluation index system, uses the improved entropy method to measure the digital economy development level of each province, and then constructs the static spatial panel model and dynamic spatial panel model. And based on the empirical analysis of multiple spatial weight matrices, the influence of provincial trade openness on the development of digital economy under the double cycle background is analyzed. The results show that:(1) there are obvious regional differences in the level of digital economy among provinces in China. The eastern region is the best, while the central region and the western region are similar; (2) there is a positive spatial correlation in the development level of digital economy among provinces in China; (3) The trade openness of China's provinces has an obvious positive influence and spatial spillover effect on the development of digital economy. The driving effect of local trade openness on the development of local digital economy is sustainable, but the driving effect on the development of digital economy in neighboring regions is not sustainable; (4) From the perspective of sub-region, the influence of the eastern regional trade openness on the digital economy has obvious spatial diffusion effect, while that of the central and western regional trade openness on the digital economy is slightly weak, which mainly belongs to the "siphon effect" mode.

The following suggestions are given. Firstly, the Chinese government needs to further form regional spatial aggregation of digital economy development and lay the foundation for high-quality development of internal circulation. It is necessary to give full play to the radiating effect of digital economy within the region and build a coordinated development network of digital economy within the region. The development of digital economy is not only conducive to the development of the region, but also can break the regional limitations, cross the constraints between regions, and achieve spatial spillover effect. Through the application of digital technology, it is possible to establish a coordinated development network between different regions, realize the aggregation of digital products between regions, expand the division of labor and cooperation between regions, and narrow the technological gap between regions. Secondly, China needs to further improve the pattern of opening up to the outside world and improve the mechanism of external circulation to promote internal circulation. Trade openness plays a significant role in promoting the digital economy of both the local region and surrounding regions. Therefore, in the process of implementing the double circulation strategy, the government should continue to strengthen the development of trade openness, make full use of policy guidance and ensure the improvement of the level of trade openness of all provinces. At the same time, it needs to give full play to the diffusion role of trade openness in advantageous regions and to promote cross-regional coordination and optimization of trade openness to maintain balanced distribution among regions. Thirdly, China needs to adopt differentiated strategies for "promoting digital economy through opening up" in different regions. The eastern China can continue to increase the level and intensity of opening-up through pilot free trade zones, free trade ports and other pilot measures, and drive the higher quality development of digital economy in the whole eastern region. While in the central and western regions, in terms of trade opening, they can make use of the advantages of urban economic circle, such as Chengdu-Chongqing dual city economic Circle, to speed up the flow of regional factors and the aggregation of resources and industries, deepen cooperation and reduce vicious competition. In addition, rich natural resources such as relatively low labor and land costs can be utilized to establish trans-regional trade cooperation industrial parks to expand the spatial spillover effect of trade openness to promote the development of digital economy in the surrounding regions, hindering the "siphon effect" phenomenon.

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References

[1] Knickrehm. M, Berthon. B, Daugherty. P. Digital disruption: The growth multiplier. Accenture Strategy, 2016.

[2] Bukht. R, Heeks. R. Defining, conceptualizing and measuring the digital economy. Development Informatics working paper, 2017.

[3] HE Da’an. Current situation and future development of China's digital economy, Governance Research,2021,37(03):5-15+2.

[4] YAO Zhanqi. Research on the impact of digital economy on China's foreign trade competitiveness. Problem of finance and economics research,2022(01):110-119.

[5] LIUYING Hengtai, YANG Lina. Spatial correlation network structure and influencing factors of China's digital economy output. Journal of Technical Economics,2021,40(09):137-145.

[6] DENG Feng, REN Zhuanzhuan. Information Network, high-tech industrial agglomeration and industrial green transformation. Economic Jingwei,2021,38(03):76-85.

[7] CAI Tiantian. “Trade openness, technology spillover and working hours of floating population: Empirical evidence based on dynamic monitoring survey of floating population in 2016,” Price Monthly,2021(08):38-47.

[8] XIANG Shujian, XU Yingchao. Foreign trade opening, human capital accumulation and enterprise technological innovation. The Journal of Production and Economics Review,2021,12(01):68-84.

[9] GUO Cece, NIHE Yongle. Trade opening, market distortion and Regional income gap: An empirical study on the mediating effect of labor mismatch. Journal of Southwest University for Nationalities (Humanities and Social Sciences Edition),2020,41(03):125-134.

[10] LeSage. J, Pace R. K. Introduction to spatial econometrics. Chapman and Hall/CRC, 2009.