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Spatial Effects of Digital Economy and Foreign Direct Investment—A U-shaped relationship

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Abstract: Is the development of digital economy necessarily beneficial to foreign direct investment (FDI)? Based on panel data of Chinese prefecture-level cities from 2011-2019, the article empirically tests the spatial spillover effects between the digital economy and FDI using a two-way fixed effects model. The results show that FDI inflows between cities have significant spatial correlation, and a city's digital economy development level has an inverted U-shaped relationship with its geographic and economic proximity to urban FDI inflows.

1. Introduction

The digital economy as the future direction of technology development, its impact on FDI is worthy of deeper investigation. In the age of the digital economy, China encourages the thorough integration of the digital economy into all areas of the economy and pulls the real economy through the digital economy. This is a crucial strategy for boosting global competitiveness and market vitality. With the quick advancement of digital technology, a variety of new economic structures have emerged, drastically altering society and our way of life[23] (Zhan & Ouyang, 2018). Data has accelerated the digitalization of existing businesses and given rise to new sectors including network offices, digital governance, and digital healthcare as the primary production component of the digital economy. These aspects of the digital economy give China a favorable setting and atmosphere in which to draw global investment. China's foreign direct investment has consistently ranked second globally in 2020 despite the extremely challenging climate for foreign investment, which is due to China's aggressive policy for the growth of its digital economy. To maximize the usefulness of FDI, it is crucial to investigate the research of the digital economy and FDI.

The digital economy has an impact on FDI by changing traditional FDI motives. Previously, FDI had a market-seeking motive to avoid trade barriers in the host country[7] (Dunning, 1998). Now, enterprises must undergo digital transformation in the digital economy, and knowledge assets are more critical than ever in this process. Therefore, FDI primarily pursues knowledge-based technologies and global knowledge assets rather than markets[8] (Eden, 2016). The growth of the digital economy has made businesses more driven to enter global markets. The growth of an inter-regional digital economy will increase market size and boost economic efficiency because of the network impact of digital products. The value of the product will rise with the number of consumers, and the market's growth will encourage more businesses to make direct international investments (Choi, 2010). Additionally, the low-cost of Internet transmission and the dependability of information management software minimize the prices of lengthy and complicated business transactions, producing a cost advantage that encourages companies to conduct their production operations globally[1] (Banalieva & Dhanaraj, 2019).

By altering FDI's motivation, the expansion of the digital economy has an impact on FDI and its location choice, but does the digital economy necessarily encourage FDI? Multinational corporations may now provide goods and services to clients overseas in digital form thanks to the growth of the digital economy. Businesses can also more readily reach global markets through export and foundry without making significant outbound investments. Companies can use digital technology to operate across borders and only partially outsource inefficient tasks, which reduces the necessity for foreign investment[18] (Rangan & Sengul, 2009). In addition, as digital technologies like artificial intelligence, 5G, and blockchain advance, low-end labor factors can be effectively replaced[9] (Frey & Osborne, 2017). This increases total factor productivity, which in turn increases excess capacity in some businesses and reduces the demand for foreign direct investment from multinational corporations[23] (Zhan & Ouyang, 2018).

In conclusion, there is disagreement among researchers about how the digital economy influences FDI. This study contends that there is a U-shaped relationship between the influence of FDI and the digital economy. There have been few studies discussed from this angle, and there have been fewer assessments of the connection between the two. Therefore, a thorough investigation of the effect of the digital economy on FDI and its mechanism of action is important for study. In order to study the U-shaped relationship impact of the digital economy on FDI, this paper uses 250 prefecture-level and above regions in China from 2011 to 2019 as a sample. It focuses on the spatial spillover effect of the digital economy on FDI.

The marginal contribution of this study may be that by developing a U-shaped model of the digital economy and FDI, it differs from earlier studies that came to the conclusion that these two variables are linearly related, offering a fresh angle for the investigation of their relationship. The nonlinear spatial spillover impact of the digital economy on FDI. To offer fresh guidelines for the growth of the digital economy in order to support the expansion of China's FDI in the challenging context of global commerce.

2. Literature review and hypotheses

The scholars' perspectives on how the digital economy would affect FDI primarily fall into two categories. According to several academics, FDI benefits from the growth of the digital economy. Businesses can access each nation's legislation, regulation, and market data via the Internet, and they can also gather information with the aid of social media and other online platforms. Additionally, direct communication with investees is feasible via emails and web conferences, which significantly lessens the issue of information asymmetry. It recognizes the importance of the informational link in space and lessens the risk associated with joining international markets. In addition, having enough information gives management the confidence to make international investments and helps them consider disparities between domestic and overseas markets as less significant[10] (Goldfarb & Tucker, 2019). Local economic growth is encouraged by the host nation having a greater degree of the digital economy. By raising the host country's international competitiveness, the digital economy draws investment from the home nation[6] (Desbordes & Wei, 2017). There is a positive relationship between the diffusion of ICT represented by the Internet and FDI[19] (Shirazi, Gholami, & Higón, 2010). An key locational element for FDI is the level of Internet growth, with a 10% increase in the number of Internet hosts or users in a destination increasing the size of foreign investment by multinational corporations by 2%.[3]-[4] (Choi, 2003, 2010). The digital economy is widely recognized as a way to change how industries innovate their products and as a key to gaining a competitive advantage[17] (Müller, Fay, & Vom Brocke, 2018). The ability of businesses to innovate technologically is also improved by the digital economy[5] (Corcoran & Gillanders, 2015), and there is a positive correlation between the increased level of technological innovation in a region and the FDI it absorbs[2] (Barrell & Pain, 1999).

According to several academics, the growth of the digital economy has hampered FDI. The term "Born Global Firmsand Accidental Internationalists" refers to SMEs that expand internationally using internet channels[13] (Hennart, 2014). The growth of the digital economy has made it possible for SMEs to immediately access global markets through online marketplaces like eBay and Amazon without having to set up a permanent presence in the host country and incur FDI location charges [8](Eden, 2016). SMEs are more likely to internationalize by purchasing business services through online platforms than by purchasing it internally. The development of the digital economy has reduced SMEs' willingness to FDI[14] (Hui, Saeedi, Shen, & Sundaresan, 2016). Large multinational corporations can reach worldwide markets more readily by exporting and OEM without making a disproportionate amount of overseas investment[18] (Rangan & Sengul, 2009). As digital technology develops, MNCs can participate fully in global market transactions without a physical economy, which could result in a drop in FDI[1] (Banalieva & Dhanaraj, 2019).

An essential feature of the digital economy is the compression of spatial and temporal distances through efficient information transfer, which enhances the breadth and depth of inter-regional economic activity linkages. An empirical examination of panel data from 48 U.S. states focused on the spatial spillover effect from informatization[22] (Yilmaz, Haynes, & Dinc, 2002). From the perspective of knowledge and technology diffusion, there are differences in the spillover distances of informatization[15] (Keller, 2002). The spatial spillover effects of the digital economy are also manifested in other ways. The development of the Internet has shortened spatial distance. The digital economy has expanded the consumption space and production space, breaking the original spatial boundaries of the market, which is conducive to the formation of a larger development pattern of production and consumption, and increasing the innovation output of enterprises from both the supply and demand sides[21] (Xiao, Wu, Liu, & Xie, 2018). The digital economy has a significant spatial spillover effect on the resource allocation of technology enterprises, indicating that the development of the digital economy helps to form a development pattern of collaborative innovation among enterprises[16] (Li & Jian, 2022). The digital economy ought to affect FDI spatially as well.

Based on the above analysis, the following hypotheses are proposed.

H. Through the spatial spillover effect, the digital economy can act on FDI in neighboring regions.

3. Methodology

3.1 Model Setting

To discuss the spatial spillover effect of the digital economy on FDI, it is expanded into a spatial panel econometric model, as shown in equation (1).

$$lnFDI_{it} = \alpha_0 + \rho WlnFDI_{it} + \lambda_1 WDige_{it} + \lambda_2 WDige_{it}^2 + \lambda_3 WZ_{it} + \alpha_1 Dige_{it} + \alpha_2 Dige_{it}^2 + \sum_{j=3}^{7} \alpha_j Z_{it} + \mu_i + \delta_t + \varepsilon_{it} \quad (1)$$

Where ρ represents the spatial autoregressive coefficient and W is the spatial weight matrix. λ_1、λ_2, and λ_3 are the elasticity coefficients of the core explanatory variables as well as the spatial interaction terms of the control variables. When $\rho = 0$, the spatial Durbin model can be simplified to a spatial lag model (SAR), and when $\lambda_1 + \lambda_2 + \sum_{j=3}^{7} \alpha_j \, (\alpha_1 + \alpha_2) = 0$, the spatial Durbin model (SDM) can be simplified to a spatial error model (SEM). The spatial lag model (SLM) and the spatial error model (SEM) can be considered special forms of the spatial Durbin model (SDM)[12]. (Vega & Elhorst, 2015).

3.2 Variable selection and data sources

Explained variable: foreign direct investment (FDI). The information was gathered from the China City Statistics Yearbook and the statistical yearbooks of each province and city, which show how much actual foreign investment was used in the whole city during the current year.

Explanatory variable: Level of development of digital economy (Dige). The five indicators of telecommunication business income, the number of employees in the computer services and software industry, the number of Internet broadband access subscribers, the number of cell phone subscribers, and the digital inclusive finance index were dimensioned down by principal component analysis and logarithmically processed to obtain digital economy of prefecture-level cities in China in a comprehensive manner[24] (Zhao, Zhang, & Liang, 2020). Among them, the data of the Digital Inclusive Finance Index was compiled by the Digital Finance Research Center of Peking University and Ant Financial Services Group[11] (Guo et al., 2020). The remaining indicators are obtained from the China City Statistical Yearbook.

Control variable: Level of economic development (GDP). The higher the level of regional economic development, the more favorable it is to attracting FDI. The logarithm of regional GDP was selected to characterize the level of regional economic development, and the data were obtained from the China City Statistical Yearbook. Openness to the outside world (Trad). The more open a region is, the more it attracts FDI. The proportion of import and export trade to GDP is selected to measure regional openness to the outside world, and the data are obtained from the National Bureau of Statistics. Urban population density (Dens). The higher the population density of a region is, the better it is for reducing the flow of people and goods and the cost of knowledge dissemination. The higher the population density of a region, the better it is for attracting FDI. The logarithm of the number of people per square kilometer is chosen to characterize the regional population density, and the data is obtained from the statistical yearbooks of Chinese provinces. Science and technology innovation level (CI). FDI prefers to invest in regions with a higher level of science and technology innovation. The higher the level of science and technology innovation in a region, the more attractive it is for foreign investors. The logarithm of the number of regional patent applications is selected to characterize the level of regional science and technology innovation, and the data is obtained from the CNRDS database. Marketability (Mard). The marketization index is used to measure the relative process of marketization in each region. The higher the degree of regional marketization is, the better it is to attract foreign investment. The Fan Gang marketization index is selected to measure the degree of regional marketization[20] (Wang & Fan, 2004).

Table 1: Descriptive Statistics.

Variables	Observations		Mean	Std. Dev.	Min	Max
FDI	2250		10.43	22.80	0	308.3
Dige	2250		8.710	0.920	6.190	13.56
GDP	2250		7.480	0.890	5.130	10.55
Dens	2250		5.880	0.880	1.880	8.840
CI	2250		7.850	1.550	3	12.45
Mard	2250		8.380	1.480	4.140	11.49
Trad	2250		0.190	0.290	0	2.370

The sample selected in this paper is the panel data of 250 prefecture-level and above cities in China from 2011 to 2019. The linear interpolation method is used to fill in the data due to a small number of missing values. Meanwhile, to avoid the effect of outliers, all continuous variables are shrunken at the 1% and 99% quartiles. The results of the descriptive statistics of the sample are shown in Table 1.

4. Results

4.1 Analysis of spatial spillover effect

4.1.1 Spatial correlation test

If there is a correlation of economic variables between neighboring spatial units, then traditional non-spatial panel models may produce estimation bias. Therefore, before building a spatial econometric model, the variables are first tested for spatial correlation to confirm the suitability of a spatial econometric model for further analysis. Moran's I index was used to test the variables for spatial correlation. Based on the geographic distance weight matrix and economic weight matrix, stata 16.0 was used to calculate the region-wide Moran's I value of FDI. As shown in Table 2, the region-wide Moran's I values of FDI variables for each year from 2011-2019 are significant at the 1% significance level, indicating a significant spatial correlation of FDI among cities.

Table 2: Moran's I.

	Geographic weight matrix				Economic weight matrix			
	lnFDI		lnDige		lnFDI		lnDige	
Year	Moran's I	Z	Moran's I	Z	Moran's I	Z	Moran's I	Z
2011	-0.055***	-21.013	-0.026***	-8.837	0.345***	10.099	0.226***	6.651
2012	-0.062***	-23.963	-0.019***	-5.979	0.339***	9.928	0.213***	6.283
2013	-0.063***	-24.069	-0.022***	-7.377	0.327***	9.571	0.223***	6.579
2014	-0.059***	-22.678	-0.016***	-4.828	0.297***	8.707	0.214***	6.322
2015	-0.046***	-17.109	-0.016***	-5.006	0.273***	8.019	0.204***	6.023
2016	-0.053***	-20.249	-0.016***	-5.001	0.267***	7.841	0.217***	6.410
2017	-0.060***	-22.954	-0.016***	-4.939	0.240***	7.054	0.208***	6.149
2018	-0.050***	-19.054	-0.014***	-4.236	0.199***	5.872	0.192***	5.684
2019	-0.051***	-19.336	-0.015***	-4.351	0.171***	5.044	0.190***	5.640

Unstandardised beta coefficients with robust standard error in parentheses
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, ǂ $p < 0.1$

4.1.2 Spatial model selection

Before considering the spatial effect, LM and robust LM tests were conducted to determine whether there was spatial autocorrelation in error and lagged terms, which were used to determine whether spatial effect analysis could be conducted between the digital economy and FDI. The test results are shown in Table 3. The original hypothesis that the error and lagged terms do not have spatial autocorrelation is rejected at the 1% level for both the LM test and the robust LM test for the geographic weight matrix. For the spatial lag term test of the economic weight matrix, the original hypothesis of no spatial autocorrelation of the lag term was rejected at the 1% level for both the LM test and the robust LM test. For the spatial error term test of the economic weight matrix, the original hypothesis of no spatial autocorrelation of the error term was rejected at the 5% level when the LM test was performed. In contrast, the original hypothesis of no spatial autocorrelation of the error terms was accepted when the robust LM test was conducted. In summary, the LM test determined the spatial correlation, and the spatial effect analysis between the digital economy and FDI could be conducted.

Table 3: Spatial spillover effect.

	(1)	(2)
Variables	Geographic weight matrix	Economic weight matrix
Dige	-0.516**	-0.731***
	(0.220)	(0.224)
$Dige^2$	0.0308**	0.0442***
	(0.0127)	(0.0130)
W×Dige	37.15***	
	(5.855)	
W×$Dige^2$	-2.339***	
	(0.380)	
ρ	-0.993***	-0.0794**
	(0.267)	(0.0365)
$Sigma^2$_e	0.104***	0.111***
	(0.00303)	(0.00330)
LR_Direct		
Dige	-0.621***	-0.724***
	(0.225)	(0.230)
$Dige^2$	0.0373***	0.0437***
	(0.0130)	(0.0134)
LR_Indirect		
Dige	19.41***	0.0536*
	(4.830)	(0.0276)
$Dige^2$	-1.220***	-0.00324**
	(0.314)	(0.00164)
LR_Total		
Dige	18.79***	-0.670***
	(4.850)	(0.215)
$Dige^2$	-1.183***	0.0405***
	(0.316)	(0.0125)
LM_spatial_lag	39.322***	11.661***
LM_spatial_error	104.941***	4.819**
Robust_LM_spatial_lag	62.414***	6.860***
Robust_LM_spatial_error	128.033***	0.018
LR_spatial_lag	60.38***	0.75
LR_spatial_error	30.51***	2.78
Wald_spatial_lag	63.76***	3.78
Wald_spatial_error	63.78***	5.83
Hausman test	64.63***	65.81***
Controls	Yes	Yes
Time FE	Yes	Yes
City FE	Yes	Yes
N	2250	2250
R^2	0.538	0.574

Unstandardised beta coefficients with robust standard error in parentheses
***$p < 0.001$, **$p < 0.01$, *$p < 0.05$, ǂ $p < 0.1$

The LR and Wald tests were further used to select the model used for spatial effect analysis. As can be seen from the results in Table 3, when the geographic weight matrix is used, the estimation results of both the Wald test and the LR test reject the original hypothesis of no spatial lag and spatial error at the 1% level, which means that the SDM model is more appropriate. When the economic weight matrix is used, the estimation results of both the Wald test and LR test accept the original hypothesis of no spatial lag and spatial error, and the SDM model degenerates to the SAR model, which is more appropriate to be used. Further, the Hausman test is used to test whether the fixed-effect or random-effect model is used, and the test results indicate that the fixed-effect model is more appropriate. Comprehensive analysis of the above, this paper finally adopts the double fixed spatial Durbin model (SDM) based on the geographic weight matrix and the double fixed spatial lag model (SAR) based on the economic weight matrix to test the spatial spillover effect of the digital economy on FDI.

4.1.3 Spatial effects regression results

The coefficients of the primary term of the digital economy on FDI under the geographic distance matrix and the economic distance matrix are significantly negative at the 5% significance level. The coefficients of the squared term are significantly positive at the 5% level. The two show a U-shaped relationship, consistent with the previous findings and further confirms the previous conclusions. In the interaction term of the digital economy and spatial weight, the primary term is significantly positive at 1% significance level. The coefficient of the squared term is significantly negative at 1% level, indicating that the digital economy of the region shows an inverted U-shaped relationship with the FDI of neighboring cities, which is contrary to the conclusion of the region. In this paper, the direct and indirect effects of the digital economy on FDI are given by partial differential decomposition. In the estimation of the direct effect, the coefficient of the primary term of the digital economy is significantly negative at the 1% level. The coefficient of the squared term is significantly positive at the 1% level, indicating that the direct effect of the digital economy on FDI inflows shows a U-shaped relationship, which further confirms the conclusion of H1. In the estimation of the indirect effect, the estimation results show the opposite characteristics, that is, the increased level of digital economy development in local cities has a facilitating effect on FDI inflows to their economies or geographically neighboring cities, but this facilitating effect tends to diminish with the development of the digital economy. When the digital economy is sufficiently developed, this promoting effect disappears, and the inhibiting effect starts to appear so that FDI keeps decreasing. This indicates that the development of the digital economy makes the city's FDI outflow to cities in geographical or economic proximity. With the further development of the digital economy, the "siphon effect" phenomenon occurs, in which the city attracts FDI from cities in close geographic or economic proximity, crowding out FDI resources from surrounding cities.

5. Conclusion and Insights

5.1 Conclusion

This paper analyzes the relationship between the digital economy and FDI at the theoretical level. Since researchers have controversies about the influence relationship between the digital economy and FDI, this paper tests whether there is a U-shaped curve relationship between the digital economy and FDI through the U-shaped curve effect model, and the results show that there is a U-shaped curve relationship between the two. Then, based on calculating the Moran index and conducting LM test on the sample to determine the existence of spatiality, the spatial effect analysis using the geographical weight matrix based on the SDM model and economic weight matrix based on the SAR model was determined by LR test and Wald test. The results showed that the digital economy of cities in this region showed an inverted U-shaped relationship with FDI in neighboring regions. The conclusions obtained are as follows.

1) With the gradual development of the digital economy, multinational enterprises will concentrate some of the links in their home countries or outsource them, which will have some impact on FDI in

China to a certain extent. Nevertheless, the growing promotion of the digital economy will counteract this negative effect, and ultimately the growth of the digital economy will increase China's investment appeal to foreign investors.

2) The improvement of the digital economy shows a non-linear inverted U-shaped relationship for the FDI inflow to the neighboring cities of the city.

5.2 Insights

Based on the above findings, this paper proposes the following policy recommendations.

1) The diffusion of digital technology can promote the development of other industries, boost production and reduce transaction costs. In order to improve the ability of the digital economy to attract foreign investment, it is necessary first to strengthen the digital economy itself, including promoting the construction of digital economy infrastructure, digitally transforming traditional infrastructure, increasing the comprehensive application of 5G, big data, artificial intelligence, and other technologies, guaranteeing the penetration of digital infrastructure into all scenes of life, driving the digitization of industries with digital industrialization, stimulating market vitality, and attracting FDI and joint development.

2) Good transportation facilities and financial technology will strengthen the ability of the region to attract foreign investment, and the planning and construction of a digital economy industrial park can better attract and utilize FDI. To develop digital economy and address the issue of the unbalanced development of the digital economy, China should stick to the approach of "channeling computing resources from the east to the west."

3) China cannot function without its open policy since it is a big market for foreign investment. This shows that foreign investment policies that align with the direction of development of the times are desirable to foreign investors. Scientific and reasonable introduction of foreign direct investment, improve the quality of foreign investment, through the appropriate formulation of foreign investment policy, improve the foreign investment market planning, improve the utilization efficiency of foreign investment, create a relatively fair business environment.

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