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Impacts of Digital Economy on Urban Entrepreneurial Competencies: A Spatial and Nonlinear Perspective

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Abstract: The vigorous rise of the digital economy not only affects the dynamic system and development path of entrepreneurial activities, but also brings new opportunities to enhance urban entrepreneurial competencies. The purpose of this paper is to investigate whether the digital economy supported by digital technologies can become a new kinetic energy that can enhance urban entrepreneurial competencies in the context of the "New Normal". Based on the sample of 286 cities in China, this paper investigates the temporal and spatial characteristics of urban entrepreneurial competencies and analyzes the spatial effect of the digital economy on urban entrepreneurial competencies using the spatial dynamic panel Durbin model. Furthermore, this paper examines whether the impact of the digital economy on urban entrepreneurial competencies has a "threshold effect" in different business environments by using threshold spatial dynamic panel model. It is found that: (1) Urban entrepreneurial competencies have obvious spatial dependence; (2) The digital economy harms the entrepreneurial competencies of neighboring cities; (3) In different business environments, the impact of the digital economy on urban entrepreneurial competencies shows obvious non-linear characteristics.

Keywords: digital economy; urban entrepreneurial competencies; non-linear effect; spatial effect; threshold spatial dynamic panel model (TSDPM)

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1. Introduction

In the background of the mobile internet era, digital technology—as the primary productive force of the digital economy—plays an important role in promoting the comprehensive upgrading of industry and society. The continuous emergence of digital technologies such as artificial intelligence and big data has spawned many new business formats and new industries, brought a large number of opportunities for exploring and developing digitalization, and also set off a new wave of entrepreneurship [1–3]. A large number of entrepreneurs are looking for business opportunities around smart hardware industries, such as smart homes, unmanned aerial vehicles, and industrial robots. These emerging entrepreneurial firms have become the representatives of new economic business formats. A large number of "Unicorn Enterprises" such as DJI (A drone brand under SZ DJI Technology Co., Ltd., which products account for over 70% of the global market share. Its flying platforms and handheld devices are sold in over 100 countries and regions around the world.) and DiDi Chuxing (It is now one of the world's largest ride-hailing companies, serving more than 493 million users across the Asia-Pacific, Africa, Latin America, Central Asia, and Russia.) have emerged. According to the 2021 China Unicorn Enterprise Development Report, the number of China's unicorn enterprises reached 251 in 2020. Enterprises related to digital technologies such as internet finance, cloud services, artificial intelligence, and big data, reached 143, accounting for 56.97%. The digital economy has gradually become the key link in entrepreneurial practice, which profoundly affects the development of economic society.

As China's economy enters the "New Normal", the traditional way of stimulating economic growth through investment and export is unsustainable. Innovation-driven entrepreneurship and entrepreneurship-activated economy have become the only ways to achieve high-quality development [4]. Cities are indispensable space carriers to strengthen entrepreneurial competencies and promote digital economy development [5]. The vigorous rise of the digital economy not only affects the dynamic system and development path of entrepreneurial activities but also brings new opportunities to enhance urban entrepreneurial competencies. However, while using the digital economy as a new engine to promote entrepreneurial activities and high-quality economic development, problems such as development imbalance, governance dilemmas, and digital gaps have gradually emerged. It has brought about certain obstacles to improving urban entrepreneurial competencies. Can the digital economy supported by digital technologies as a new driving force enhance urban entrepreneurial competencies in the context of the "New Normal"? With the development of digital technologies, the spatial mobility of innovation factors is becoming more frequent and convenient. Does the digital economy have a certain spatial rule on the influence of urban entrepreneurial competencies? Business environments, such as the market environment, legal environment, financial environment, and policy environment, often differ between cities. Is the digital economy empowering urban entrepreneurial competencies non-linear due to the differences in the business environment? Clarifying the above issues has important practical significance for grasping the "digital opportunities" in the digital economy era and effectively promoting the improvement of urban entrepreneurial competencies.

To this end, based on the panel data of 286 cities in China from 2011 to 2019, this paper investigates the temporal and spatial characteristics of urban entrepreneurial competencies, and constructs the spatial dynamic panel Durbin model (SDPDM) to explore the spatial effects of the digital economy on urban entrepreneurial competencies. Furthermore, this paper selects business environment indicators such as the market environment, legal environment, science and technology environment, financial environment, and policy environment as threshold variables, and uses the threshold spatial dynamic panel model (TSDPM) to examine whether the impact of the digital economy on urban entrepreneurial competencies has a "threshold effect" in different business environments. Combined with those findings, this paper puts forward some policy implications on how to make better use of the digital economy to empower urban entrepreneurial competencies, and provides a policy basis for the digital transformation and high-quality development of the city.

The rest of this paper runs in the following order. Section 2 reviews the literature associated with the relevant topic. Section 3 presents the study design. Section 4 introduces the data and variables. Section 5 shows the empirical analysis. Section 6 reports the main conclusions and offers policy recommendations.

2. Literature Review

By virtue of the boom of the internet of China, the combination of digital technology and finance gives birth to digital economy) [6]. As the notion concerning the digital economy is introduced, the relation between digital economy and urban entrepreneurial competencies becomes a hotspot of research.

2.1. Digital Economy

As digital technology penetrates various fields of economy and society, the definition of the digital economy has gradually broken through the limitations of ICT (Information and Communication Technology) and e-commerce, and has become a new economic format brought about by digital technology with the characteristics of digitalization and informatization [7,8]. Measurement of the digital economy is very important. However, due to the large number of industries involved in the digital economy and the lack of geographical limitations, it is difficult to accurately quantify the digital economy [9]. Scholars attempt to use different methods from different dimensions to measure the digital economy, which has

to some extent enriched the measurement system of the digital economy [10]. On the basis of measuring the digital economy, some scholars try to explore the actual impact of the digital economy on different fields [11]. At the macro level, these discussions mainly involve the impact of the digital economy on economic growth [12,13], the transformation and upgrading of industrial structure [14,15], the total factor productivity [16,17], the regional innovation efficiency [18,19], the urban-rural differences [20], the ecological environmental governance [21,22], sustainable employment [23], and the development of neighboring countries' economies [24,25]. At the micro level, these mainly involve the impact of the digital economy on the enterprise technology diffusion [26], the enterprise innovation [27], the entrepreneurial performance [28], the efficiency of resource allocation [29], the risk of households falling into a debt trap [30], and the transformation of management [31,32].

2.2. Urban Entrepreneurial Competencies

Urban entrepreneurial competencies show the entrepreneurial resources of the city and the entrepreneurial competencies of entrepreneurs. Most of the existing studies suggest that urban entrepreneurial competencies play an increasingly important role in regional development [33]. It attracts investment and people to places through access to tangible and intangible resources, and stimulates the formation of local business and social networks [34,35], considering that the improvement of urban entrepreneurial competencies can gain more sustainable revenue by reducing the unemployment rate. Della Lucia and Trunfio emphasize that the improvement of urban entrepreneurial competencies can not only stimulate the development of new service infrastructure, but also attract new investment, new residents, and a greater flow of visitors [36]. Liang et al. suggest that urban entrepreneurial competencies can respond to the demands of society by absorbing employment, improving efficiency, and increasing social value [37].

2.3. Digital Economy and Entrepreneurial Competencies

The relationship between the digital economy and entrepreneurial competencies has been paid much attention theoretically and empirically. In the theoretical analysis, there are mainly two different views [1]. The first one is that the development of the digital economy is conducive to improving entrepreneurial competencies [38]. The second one is that the development of the digital economy is not conducive to improving entrepreneurial competencies. From the viewpoint of enterprise survival, both the content and structure of digital technology are modifiable, inclusive, and open, which will generate a negative impact on the birth and growth of start-ups [39]. In particular, the emergence of digital technology may destroy the existing entrepreneurial environment and ecology, and endanger the start-ups [40]. From the viewpoint of enterprise development, the inclusiveness and openness of digital technologies hinder start-ups from accessing resources to a certain extent, increase the volatility and uncertainty of demand for production factors, and lead to moral hazards [41]. In the empirical analysis, scholars mainly discuss the impact of the digital economy on entrepreneurial competencies from the perspective of digital finance. Related studies point out that digital finance not only helps to alleviate the loan constraints of individual entrepreneurship and the constraints of insufficient social relations resources [42], but also significantly promotes inclusive growth through entrepreneurship [43].

Up to now, limited by the availability of data related to the digital economy, most studies are carried out at the provincial or regional (including urban cluster) level. Existing empirical studies ignore the spatial correlation between the digital economy and urban entrepreneurial competencies, resulting in a certain bias in the results of empirical analysis. Few studies investigate the spatial effect and the non-linear effect of the digital economy on urban entrepreneurial competencies. Based on the realistic background of China, this paper makes a quantitative analysis of the relationship between the digital economy and urban entrepreneurial competencies, revealing the spatial effect of the digital economy empowering urban entrepreneurial competencies, which provides city-level empirical evidence. On the other hand, by incorporating business environment factors into the

research framework, this paper investigates the possible non-linear relationship between the digital economy and urban entrepreneurial competencies, and enriches the related research.

3. Study Design

3.1. Analysis of Temporal-Spatial Characteristics

Temporal-spatial characteristics involve two aspects. First, based on the panel data of 286 cities in China from 2011 to 2019, we calculate the coefficient of variation of urban entrepreneurial competencies and the digital economy, and analyze their temporal characteristics referring to the practice of [44]. Second, by using Exploratory Spatial Data Analysis (ESDA), we examine the spatial characteristics of urban entrepreneurial competencies and the digital economy. According to [45], the non-geospatial concept weight matrix cannot effectively measure the spatial effect, and the estimated coefficients may generate "interpretation pitfalls". Therefore, we use the geographic adjacency weight matrix ($\mathbf{W^A}$) and the geographic distance weight matrix ($\mathbf{W^D}$) to describe the spatial connections of geographic units [46]. The geographic adjacency weight matrix ($\mathbf{W^A}$) means that if two spatial units are adjacent, the weight is set as 1, otherwise 0. The geographic distance weight matrix ($\mathbf{W^D}$) depicts the degree of correlation between spatial units through the reciprocal of the square of the centroid distance (It is calculated using R and an electronic map at a scale of 1:4,000,000 downloaded from the National Fundamental Geographic Information System.) between cities. The spatial autocorrelation is analyzed by Global Moran's I (*MoranI*), depicted in Equation (1):

$$MoranI = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} W_{ij}(x_i - \overline{x})(x_j - \overline{x})}{\sum_{i=1}^{n} W_{ij}(x_i - \overline{x})^2} \quad (1)$$

where W_{ij} is a spatial weight matrix with row standardization, $\overline{x} = \frac{1}{n}\sum_{i=1}^{n} x_i$, x_i is the entrepreneurial competencies (or digital economy) for the ith city. The value of the Moran's I varies from -1 to 1. A value greater than 0 points to positive autocorrelation. A value less than 0 points to negative autocorrelation. A value close to or equal to 0 points to absence of autocorrelation and the spatial distribution is random.

3.2. Analysis of Spatial Effects

When exploring the spatial effect of urban entrepreneurial competencies, the spatial econometric model can fully consider its inherent properties and its spatial dependence on neighboring cities. Therefore, the spatial econometric model is employed. There are three basic forms of spatial econometric models: spatial lag model (SLM or SAR), spatial error model (SEM), and spatial Durbin model (SDM). SDM is the general form of SLM and SEM, which simultaneously introduces the spatial lags of the explained variable and the explanatory variable. It is not only conducive to alleviating the problem of omitted variables, but also effective at capturing the spatial effect of the explanatory variables [45]. Moreover, the digital economy is not independent, and it may be affected by the development of networked digital industries of neighboring cities [47]. Accordingly, we constructed the spatial dynamic panel Durbin model (SDPDM) to investigate the spatial effect of the digital economy on entrepreneurial competencies. To be specific,

$$SU_{it} = \tau \cdot SU_{i,t-1} + \rho \cdot \sum_{j=1}^{286} W_{ij}SU_{it} + \beta \cdot Digit_{it} + \theta \cdot \sum_{j=1}^{286} W_{ij}Digit_{it} + \boldsymbol{\lambda}\mathbf{X} + \mu_i + \upsilon_t + \varepsilon_{it} \quad (2)$$

where i and t are the ith city and the tth year, respectively, $j(j \neq i)$ represents the adjacent city, SU_{it} is the urban entrepreneurial competencies, $SU_{i,t-1}$ is the time lag of urban entrepreneurial competencies, $Digit_{it}$ is the digital economy, $\mathbf{X}$ is the vector of control variables, τ is the coefficient of the explained variable with a time-lagged term, ρ is the spatial autoregressive coefficient of the explained variable, β is the estimated coefficient of the core explanatory variable, and θ is the spatial autoregressive coefficient of the core

explanatory variable, which represents the spatial effect of the digital economy. $\mathbf{W} = \sum_{j=1}^{286} W_{ij}$ is a 286 × 286 spatial weight matrix, which is the geographic adjacency weight matrix $\mathbf{W^A}$ and the geographic distance weight matrix $\mathbf{W^D}$, respectively. μ_i, v_t, and ε_{it} are spatial fixed effect, time fixed effect, and error term, respectively.

3.3. Analysis of Non-Linear Effect

Equation (2) can examine the spatial effect of the digital economy on urban entrepreneurial competencies. To further study the possible asymmetric and non-linear effects of the digital economy on urban entrepreneurial competencies, the threshold spatial dynamic panel model (TSDPM) proposed by [48] is used. This method is beneficial to empirically exploring and refining the asymmetric spatial interaction between the digital economy and urban entrepreneurial competencies [49]. Taking the TSDPM with a single threshold as an example, the estimated model is shown in Equation (3):

$$\begin{aligned} SU_{it} = \tau \cdot SU_{i,t-1} + \rho \cdot \sum_{j=1}^{286} W_{ij} y_{jt} + \beta_1 \cdot I(En_{it} \le \gamma) Digit_{it} + \beta_2 \cdot I(En_{it} > \gamma) Digit_{it} \\ + \theta \cdot \sum_{j=1}^{286} W_{ij} Digit_{it} + \boldsymbol{\lambda} \mathbf{X} + \mu_i + v_t + \varepsilon_{it} \end{aligned} \tag{3}$$

where En_{it} is the threshold variable, involving the market environment, legal environment, science and technology environment, financial environment, and policy environment; γ is the threshold value; and β_1 and β_2 represent the response coefficients of the digital economy when the threshold variable is less than or greater than the threshold value, respectively.

4. Data

We use the data stemming from the Index of Regional Innovation and Entrepreneurship in China to measure the urban entrepreneurial competencies, which is constructed by the Center for Enterprise Research of Peking University. The data relating to the digital economy mainly come from the Digital Financial Inclusion Index, jointly compiled by the Institute of Digital Finance Peking University and Ant Financial Group [50], and the "Internet Plus" urban digital economy development index released by Tencent Research Institute. The marketization index is provided by the Marketization Index of China's Provinces (2021) [51]. The data on the number of Intellectual Property (IP) first-instance cases come from the Chinalawinfo Database. The remaining data used come from the China City Statistical Yearbook.

Urban entrepreneurial competencies reflect the positive degree of entrepreneurial activities in the region [52]. According to the existing studies, urban entrepreneurial competencies are mostly measured in two ways: the number of new enterprises [4,53] and the ratio of employment to the total population [54,55]. The ratio of employment to the total population tends to fluctuate greatly with the year at the city level, and it is difficult to measure the differences in entrepreneurial competencies between regions [56]. Therefore, drawing on the idea of [57], this paper chooses the number of new enterprises (logarithmic processing), published in the Index of Regional Innovation and Entrepreneurship in China, to measure urban entrepreneurial competencies (SU).

The digital economy is a series of economic activities, which are based on digital technology, with digital platforms as the main medium and digital-enabling infrastructure as important support [10]. Referring to [4,58], the index measurement system of the digital economy is designed (Table 1). Different from the existing digital economy indicator system, the digital finance in Table 1 is further refined into "Coverage breadth of digital finance", "Usage depth of digital finance", and "Digitalization level of finance".

Table 1. Digital economy indicator measurement system.

1st-Level Indicator	2nd-Level Indicator	3rd-Level Indicator	Measurement	Attributes
Digital economy	Digital industry	Internet penetration rate	Number of internet users per 100	+
		Size of internet-related practitioners	Proportion of internet-related practitioners in urban employment, such as computer service and software	+
		Mobile telephone penetration rate	Number of mobile telephone users per 100	+
		Internet business volume	Total telecommunication services per capital	+
	Digital finance	Coverage breadth of digital finance	Coverage breadth of Digital Financial Inclusion Index	+
		Usage depth of digital finance	Usage depth of Digital Financial Inclusion Index	+
		Digitalization level of finance	Digitalization level of Digital Financial Inclusion Index	+

To facilitate comparison between indicators, the threshold method in the linear dimensionless method was used to standardize the data, as shown in Equations (4) and (5).

$$y_i = \frac{x_i - \max_{1\le i\le n} x_i}{\max_{1\le i\le n} x_i - \min_{1\le i\le n} x_i} \times k + q \tag{4}$$

$$y_i = \frac{x_i - \min_{1\le i\le n} x_i}{\max_{1\le i\le n} x_i - \min_{1\le i\le n} x_i} \times k + q \tag{5}$$

where $\max_{1\le i\le n} x_i$ and $\min_{1\le i\le n} x_i$ represent the maximum and minimum values under the same indicator. Equations (4) and (5) are suitable for the standardization of the cost-type indicator and benefit-type indicator, respectively. Parameters k and q can be explored and gradually optimized according to the actual situation and the existing experience until we find the most suitable parameters. Since the selected tertiary indicators are all positive benefit-type indicators, we refer to the method of measuring provincial digital economy by [59] and the Networked Readiness Index (NRI) published by Harvard University and the World Economic Forum. Let $k = 6$ and $q = 1$. Then, we obtain the following standardized calculation formula:

$$X_{it} = \frac{V_{it} - V_{\min}}{V_{\max} - V_{\min}} \times 6 + 1 \tag{6}$$

where V_{it} represents the raw data under the ith indicator in the tth year, and $V_{\max}$ and $V_{\min}$ represent the maximum and minimum values under the ith indicator, respectively. After data processing, all indicators are between 1 and 7. A higher value represents a higher indicator level. Equation (6) is compared in each year and there is still a lack of comparability between different statistical years. Thus, we use 2011 as base year to make the obtained indicators comparable across years. It is calculated as follows:

$$Z_{it} = \frac{V_{it} - V_{\min 0}}{V_{\max 0} - V_{\min 0}} \times 6 + 1 \tag{7}$$

where $V_{\max 0}$ and $V_{\min 0}$ represent the maximum and minimum values in the base year. Indicators processed by Equation (7) are comparable between different years, and can reflect the development of indicators over time. On this basis, we calculate the weight of the indicator using the entropy weight method. A linear weighting method is used to calculate the comprehensive evaluation index of the digital economy. The specific steps are as follows.

Step 1: Calculate the proportion of the jth indicator in the tth year $P_{it} = Z_{it} / \sum_{t=1}^{n} Z_{it}$.

Step 2: Calculate the entropy of the jth indicator $e_i = -k\sum_{t=1}^{n} P_{it}\ln(P_{it})$, where $k = 1/\ln(n)$.

Step 3: Calculate the information redundance $d_i = 1 - e_i$.

Step 4: Calculate the weight value of indicators $\beta_i = d_i/\sum_{i=1}^{m} d_i$.

Step 5: Calculate the comprehensive evaluation index of the digital economy in cities $Index_{it} = \sum_{i=1}^{m} \beta_i P_{it}$.

Step 6: Take the natural logarithm of the comprehensive index of the digital economy to ensure smoother data $Digit_{it} = \ln(Index_{it})$.

In addition, other important variables are addressed in this paper, such as city-level control variables and threshold variables that measure the business environment. Control variables include urban economic growth (Gdp), urban population density (Pop), urban education expenditure (Edu), and urban foreign direct investment (FDI). Threshold variables measuring the business environment include the market environment (Mkt), legal environment (Law), science and technology environment ($Tech$), financial environment (Fin), and policy environment (Pol). The definition of variables is shown in Table 2, and the descriptive statistics of variables are reported in Table 3.

Table 2. Definition of variables.

Category	Name	Sign	Definition
Explained variable	Urban entrepreneurial competencies	*SU*	The natural logarithm of the number of new enterprises published in the Index of Regional Innovation and Entrepreneurship in China 2020.
Core explanatory variable	Digital economy	*Digit*	See the digital economy indicator measurement system for details.
Control variables	Urban economic growth	*Gdp*	The natural logarithm of GDP per capital [60].
	Urban population density	*Pop*	The natural logarithm of the population density.
	Urban education expenditure	*Edu*	Proportion of local government expenditure on science and education in the total fiscal expenditure.
	Urban foreign direct investment	*FDI*	Foreign capital actual utilized × Central parity rate of RMB exchange rate/GDP [61]
Threshold variables	Market environment	*Mkt*	It is calculated according to the China Market Index constructed by Wang et al. (2019) [51] and the relevant data of cities at prefecture-level and above.
	Legal environment	*Law*	Add 1 to the number of intellectual property first-instance cases in cities at prefecture-level and above, and take the natural logarithm; it is used as the measure indicator of the judicial environment for regional Intellectual Property protection (Zhuang et al., 2020) [62].
	Science and technology environment	*Tech*	Referring to Han et al. (2021) [63], we use the logarithm of the number of employees in scientific research and technological service industries in the China City Statistical Yearbook as a proxy variable for science and technology environment.
	Financial environment	*Fin*	Referring to Long et al. (2015) [64], the number of banks per 100 million yuan of GDP is taken as the measure indicator of the urban financial environment.
	Policy environment	*Pol*	Using China's Municipal Fiscal Transparency Index [65].

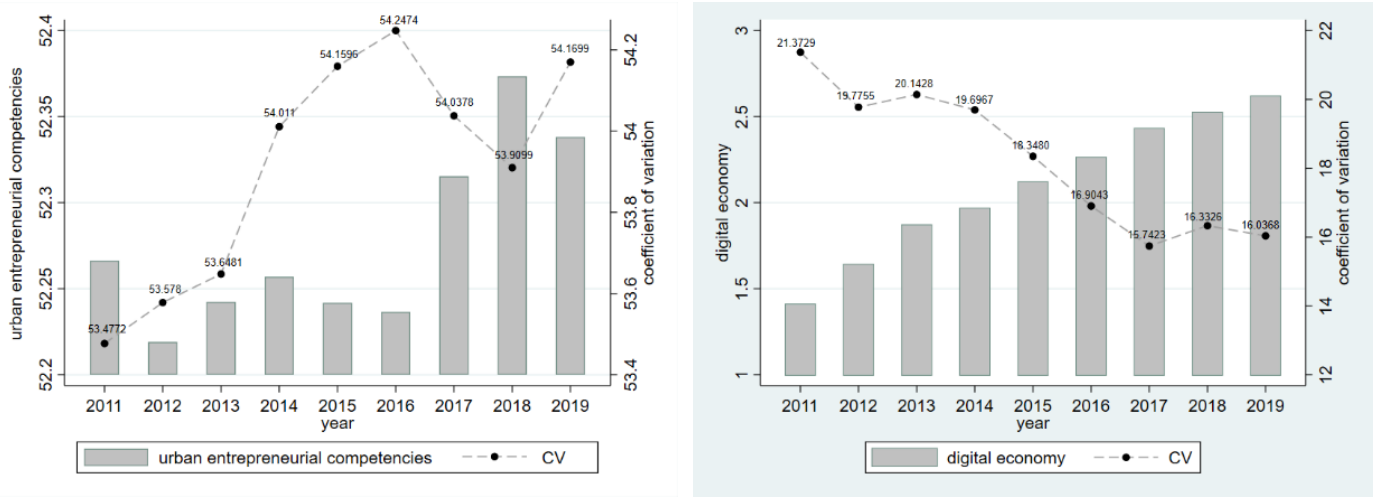
Table 3. Descriptive statistics for variables.

Variable	Mean	S.D.	Me	Min	Max	Obs
SU	52.255	28.145	52.560	2.048	100	2574
Digit	2.118	0.532	2.129	1.037	5.366	2574
Gdp	7.262	0.981	7.190	0.667	10.549	2574
Pop	5.751	0.883	5.881	2.925	7.336	2574
Edu	0.194	0.042	0.195	0.015	0.372	2574
FDI	0.156	6.048	0.013	0.000	352.562	2574
Mkt	6.895	1.683	6.780	2.330	11.400	2574
Law	3.040	2.271	2.944	0.000	9.571	2574
Tech	2.618	0.972	2.484	0.274	7.729	2574
Fin	0.451	0.426	0.360	0.098	9.384	2574
Pol	0.410	0.214	0.409	0.000	0.922	2574

5. Empirical Discussions

5.1. Temporal-Spatial Characteristics of Urban Entrepreneurial Competencies and Digital Economy

We calculate the average and the coefficient of variation of the entrepreneurial competencies and digital economy of 286 cities in China, as shown in Figure 1.



(**a**) (**b**)

Figure 1. Temporal characteristics of urban entrepreneurial competencies and digital economy. (**a**) Urban entrepreneurial competencies. (**b**) Digital economy.

Figure 1a shows that, between 2011 and 2019, China's urban entrepreneurial competencies present a dynamic change of alternating between rising and falling. The coefficient of variation of urban entrepreneurial competencies shows a dynamic change of rise and fall and rise again during the sample period. The value increases from 53.477 in 2011 to 54.247 in 2016, then decreases to 53.909 in 2018, then is reversed and quickly recovers to 54.169 in 2019. Compared to the beginning of the "Mass Innovation and Entrepreneurship" boom in 2014, the so-called "burning money entrepreneurship" driven by hot money was fading away from 2016 to 2018; the overall environment became slightly calm, and the number of entrepreneurs dropped significantly. According to data from LinkedIn, taking the proportion of internet entrepreneurial talents as an example, the proportion of professionals who started entrepreneurship in 2016 decreased by 35% compared to 2015. Starting from 2018, the Chinese government has vigorously promoted the reform of the commercial system and the need to "streamline the government, delegate power, and improve government services". Local governments have generally increased their policy efforts to promote entrepreneurship and employment, thus urban entrepreneurial competencies have been continuously improved. According to Figure 1b, China's digital economy is steadily rising.

The average of the digital economy of 286 cities has increased from 1.406 in 2011 to 2.614 in 2019, with an average annual growth rate of 7.13%, indicating that the development level of the digital economy has been significantly improved during the sample period. The coefficient of variation of the digital economy shows an approximate downward trend, indicating that the relative differences between the development level of the digital economy of cities show a dynamic change of gradually narrowing during the sample period.

Table 4 reports the test results for spatial autocorrelation of urban entrepreneurial competencies and digital economy. The result on the left shows that whether based on the geographic adjacency weight matrix or geographic distance weight matrix, the test result for the spatial autocorrelation of urban entrepreneurial competencies is always significant, and Moran's I is positive. This result means that the spatial objects of the entrepreneurial competencies of cities are dependent on each other, and the entrepreneurial competencies of a certain city will be affected by the entrepreneurial competencies of neighboring cities. The result on the right shows that the digital economy also has significant spatial autocorrelation. Since cities have obvious spatial dependence on entrepreneurial competencies and the digital economy, it is necessary to use the spatial econometric model to carry out further empirical research.

Table 4. Test results for global autocorrelation.

Year	Urban Entrepreneurial Competencies		Digital Economy	
	W^A	W^D	W^A	W^D
2011	0.068 ***	0.125 ***	0.052 ***	0.156 ***
2012	0.061 ***	0.110 ***	0.066 ***	0.204 ***
2013	0.070 ***	0.125 ***	0.077 ***	0.279 ***
2014	0.066 ***	0.122 ***	0.078 ***	0.259 ***
2015	0.070 ***	0.123 ***	0.078 ***	0.281 ***
2016	0.075 ***	0.131 ***	0.075 ***	0.298 ***
2017	0.078 ***	0.131 ***	0.080 ***	0.320 ***
2018	0.083 ***	0.154 ***	0.077 ***	0.363 ***
2019	0.085 ***	0.156 ***	0.069 ***	0.358 ***

Note: *** denotes the 1% significant level.

5.2. Spatial Effect of Digital Economy on Urban Entrepreneurial Competencies

5.2.1. Benchmark

Table 5 shows the estimation results of SDPDM with urban entrepreneurial competencies as the explained variable. Referring to Elhorst (2014) [66], this paper conducted LM tests, Wald tests, fixed effects tests, Hausman tests, and SDM simplification tests. First, the results of the Hausman test significantly reject the hypothesis of the random-effect model under different spatial weights. Second, the LR statistics of time and spatial fixed effect models show that the two-way fixed effect model is significantly better than time and spatial fixed effect models. Third, the results of the Wald test and LR test indicate that we should reject the hypothesis (SDM can be reduced to SLM or SEM). It is confirmed that the spatial lag and spatial error effects exist simultaneously. Accordingly, we use the SDPDM with two-way fixed effect for estimation.

Since the SDPDM introduces lagging factors into the regression analysis, the influence degree of the digital economy on urban entrepreneurial competencies cannot be directly obtained via Table 5. However, the following results can still be obtained: ① The estimated coefficients (τ) of urban entrepreneurial competencies with time lag are significantly positive, reflecting the path-dependence of urban entrepreneurial competencies. Thus, the early stage of urban entrepreneurial competencies is conducive to promoting the improvement of later entrepreneurial competencies. ② Both regression coefficients (ρ) of urban entrepreneurial competencies with spatial lag are significant and positive under different spatial weights. The estimation of the coefficient under the adjacency weight matrix is much greater than the corresponding value under the distance weight matrix,

which indicates that China's urban entrepreneurial competencies have spatial dependence, and that the mutual driving effect of entrepreneurial competencies between neighboring cities is stronger. ③ No matter what the spatial weight matrix is, the estimated coefficient (β) of the digital economy is significantly positive, indicating that the development of the digital economy in Chinese cities has generally promoted the improvement of local entrepreneurial competencies. ④ The estimated coefficient (θ) of the digital economy with spatial lag is significantly negative, indicating that the development of the local digital economy will play a certain inhibitory role in the improvement of the entrepreneurial competencies of neighboring cities.

Table 5. Estimation results of the SDPDM.

Variable	Urban Entrepreneurial Competencies	
	$\mathbf{W^A}$	$\mathbf{W^D}$
$SU_{i,t-1}$	0.503 *** (0.018)	0.512 *** (0.018)
$Digit_{it}$	1.530 *** (0.914)	0.311 * (0.168)
$\mathbf{W} \times SU_{it}$	1.247 *** (0.266)	0.058 * (0.029)
$\mathbf{W} \times Digit_{it}$	−3.136 *** (1.243)	−1.589 * (0.796)
Control variable	yes	yes
R-sq	0.92	0.93
| Log-L |	308.709	702.195
Obs	2574	2574
Hausman test	555.21 ***	1257.17 ***
Spatial fixed effect	7.87 ***	5.92 ***
Time fixed effect	9.54 ***	6.15 ***
Wald test	6.36 **	2.49 *
LR test	3.91 *	2.61 *

Note: The S.E. is put in (); ***, **, and * mean significance at the level of 1%, 5%, and 10%, respectively.

5.2.2. Effect Decomposition

SDPDM contains both the spatial lag term of urban entrepreneurial competencies and that of the digital economy simultaneously. Therefore, the partial differential method [67] needs to be applied to decompose the total effect into direct and indirect effects and to refine the two types of effects into long-term and short-term effects in the time dimension. The categories of effect, calculations, and decomposition results are summarized in Table 6. It is shown that whether long-term or short-term, the digital economy has an obvious stimulating effect on the improvement of local entrepreneurial competencies, but has a certain negative inhibitory effect on the entrepreneurial competencies of neighboring cities. The long-term effect of the digital economy on urban entrepreneurial competencies will be stronger than the short-term effect.

5.2.3. Robustness Discussion

To overcome the effect of the selection of statistical variables on estimation results, this paper replaced the statistical variables with similar statistical variables for robustness tests. On the one hand, we use the investment project published by the Index of Regional Innovation and Entrepreneurship in China (VCPE) as an alternative variable of the explained variable for the robustness test [57]. On the other hand, referring to Wei (2022) [68], we use the "Internet Plus" urban digital economy development index from 2014 to 2018, released by Tencent Research Institute, as an alternative variable of the core explanatory variable. Table 7 reports the estimation results after replacing the statistical variables of the explained variable and core explanatory variable. It is shown that the estimation results are

consistent with the results obtained in Table 5, confirming that the estimation results are robust and credible.

Table 6. Effect decomposition of digital economy affecting urban entrepreneurial competencies.

Category		Calculation	Urban Entrepreneurial Competencies	
			$\mathbf{W^A}$	$\mathbf{W^D}$
Short-term	Direct effect	$\left[[I-\rho W]^{-1}[\beta_k I_N]\right]^{\overline{d}}$	2.281 ** (1.014)	1.5457 * (0.7894)
	Indirect effect	$\left[[I-\rho W]^{-1}[\beta_k I_N]\right]^{\overline{rsum}}$	−1.518 * (0.923)	−0.2812 (0.8120)
Long-term	Direct effect	$\left[[(1-\tau)I-\rho W]^{-1}[\beta_k I_N]\right]^{\overline{d}}$	4.1213 ** (1.9790)	3.0515 * (1.6078)
	Indirect effect	$\left[[(1-\tau)I-\rho W]^{-1}[\beta_k I_N]\right]^{\overline{rsum}}$	−3.123 * (1.8926)	−1.5856 ** (0.6676)

Note: The S.E. is put in (); **, and * mean significance at the level of 5%, and 10%, respectively; $\overline{d}$ represents the operator that calculates the mean diagonal element of the matrix. $\overline{rsum}$ represents the operator that calculates the mean row sum of the non-diagonal element of the matrix.

Table 7. Estimation results of robustness test.

Variable	Replace Explained Variable		Replace Core Explanatory Variable	
	$\mathbf{W^A}$	$\mathbf{W^D}$	$\mathbf{W^A}$	$\mathbf{W^D}$
$SU_{i,t-1}$	0.208 *** (0.021)	0.323 *** (0.022)	0.503 *** (0.018)	0.512 *** (0.018)
$Digit_{it}$	0.068 ** (0.027)	0.069 *** (0.024)	1.655 * (0.955)	0.519 * (0.287)
$\mathbf{W} \times SU_{it}$	0.023 *** (0.002)	0.036 * (0.017)	1.246 *** (0.266)	0.057 * (0.029)
$\mathbf{W} \times Digit_{it}$	−0.107 *** (0.035)	−0.112 * (0.058)	−0.329 *** (0.126)	−1.719 *** (0.319)
Control variable	yes	yes	yes	yes
Hausman test	156.66 ***	186.73 ***	471.25 ***	1352.59 ***
Spatial fixed effect	9.27 ***	9.70 ***	20.30 **	36.26 ***
Time fixed effect	12.18 ***	19.80 ***	11.98 ***	15.03 ***
Wald test	9.34 ***	15.77 ***	6.83 ***	2.85 *
LR test	8.20 ***	15.59 ***	8.12 ***	2.96 *
Obs	2574	2574	1430	1430
R-sq	0.59	0.57	0.92	0.93

Note: The S.E. is put in (); ***, **, and * mean significance at the level of 1%, 5%, and 10%, respectively.

5.3. Non-Linear Effect of Digital Economy on Urban Entrepreneurial Competencies

Table 8 presents the threshold test results of 300 Bootstrap replications for each threshold. When the market environment is used as the threshold variable, the Bootstrap sampling results corresponding to the single and double thresholds hypothesis are both significant, while the result corresponding to the triple thresholds hypothesis is not significant. It confirms that there are double thresholds for the market environment. When the legal environment, science and technology environment, financial environment, and policy environment are used as the threshold variable, the Bootstrap sampling result corresponding to the single threshold hypothesis is significant, while the results corresponding to the double and triple thresholds hypothesis are not significant, indicating that there is a single threshold for the four external environments above. According to the threshold estimated values and the test results summarized in Table 9, the market environment can be divided into "high marketization ($Mkt > 7.260$)", "medium marketization ($5.830 < Mkt \leq 7.260$)" and "low marketization ($Mkt \leq 5.830$)"; the legal environment can be divided into "better

legal environment ($Law > 2.708$)" and "poor legal environment ($Law \leq 2.708$)"; the science and technology environment can be divided into "better science and technology environment ($Tech > 1.014$)" and "poor science and technology environment ($Tech \leq 1.014$)"; the financial environment can be divided into "better financial environment ($Fin > 0.305$)" and "poor financial environment ($Fin \leq 0.305$)"; the policy environment can be divided into "better policy environment ($Pol > 0.180$)" and "poor policy environment ($Pol \leq 0.180$)".

Table 8. Results of threshold test.

Threshold Variable	Model	Threshold Value	MSE	F-Value	*p*-Value	BS
Market environment *Mkt*	Single	5.830	25.734	35.02 ***	0.000	300
	Double	5.830 7.260	25.477	20.81 **	0.010	300
	Triple	5.830 6.320 7.260	25.363	9.33	0.600	300
Legal environment *Law*	Single	2.708	26.002	13.40 **	0.049	300
	Double	2.708 5.397	25.935	5.34	0.350	300
	Triple	-	-	-	-	-
Science and technology environment *Tech*	Single	1.014	26.069	25.36 ***	0.000	300
	Double	1.014 2.236	25.989	6.40	0.420	300
	Triple	-	-	-	-	-
Financial environment *Fin*	Single	0.305	26.043	10.16 **	0.000	300
	Double	0.305 0.459	25.982	4.81	0.460	300
	Triple	-	-	-	-	-
Policy environment *Pol*	Single	0.180	26.039	23.56 ***	0.000	300
	Double	0.180 0.759	25.485	6.10	0.267	300
	Triple	-	-	-	-	-

Note: The S.E. is put in (); ***, ** mean significance at the level of 1%, 5%, respectively; "-" represents that it does not exist.

Table 9 shows the estimation results of TSDPM when the market environment, legal environment, technology environment, financial environment, and policy environment are used as threshold variables. The results show that: (1) When the degree of marketization is low, it is difficult for the digital economy to empower urban entrepreneurial competencies, while it is conducive to the digital economy to promote urban entrepreneurial competencies when the degree is medium or high. The reason may be that the low degree of marketization tends to exacerbate the "siphon effect" of neighboring cities on the region, resulting in the outflow of local talents and other resources, and thereby weakening the incentives of the digital economy on urban entrepreneurial competencies. (2) In a better legal environment and science and technology environment, the digital economy can effectively empower urban entrepreneurial competencies. However, in poor environments, the digital economy will not only have difficulty promoting the improvement of urban entrepreneurial competencies, but may even inhibit urban entrepreneurial competencies. (3) Compared to a better financial environment, in a poor financial environment, the digital economy will have a stronger promotion effect on urban entrepreneurial competencies. (4) Regardless of the policy environment, the digital economy always promotes the improvement of urban entrepreneurial competencies, but the policy environment will influence the effect

of the digital economy on urban entrepreneurial competencies. Compared to regions in better policy environments, the promotion effect of regions in poor policy environments is relatively weak. This may be because the digital economy of regions in a better policy environment can be better at infiltrating entrepreneurial activities, and can more fully release the dividends brought by the digital economy.

Table 9. Estimation results of TSDPM.

		Threshold Variable				
Threshold Estimator		Market Environment	Legal Environment	Science and Technology Environment	Financial Environment	Policy Environment
		5.830 7.260	2.708	1.014	0.305	0.180
Digital economy	Lower regime	−2.786 * (1.407)	−0.549 (0.728)	−0.419 (7.299)	2.471 *** (0.652)	0.386 *** (0.073)
	Middle regime	1.449 *** (0.368)				
	upper regime	4.443 *** (1.174)	1.074 * (0.541)	4.263 * (2.174)	0.685 (0.734)	0.624 *** (0.231)
% of the Obs in the lower regime		25.02%	45.45%	2.56%	38.73%	17.79%
% of the Obs in the upper regime		35.31%	54.55%	97.44%	61.27%	82.21%
Control variable		yes	yes	yes	yes	yes
Obs		2574	2574	2574	2574	2574

Note: The S.E. is put in (); ***, and * mean significance at the level of 1%, and 10%, respectively.

6. Conclusions

Based on the panel data of 286 cities at the prefecture-level and above in China from 2011 to 2019, this paper investigates the temporal and spatial characteristics of urban entrepreneurial competencies and the digital economy, and tests the spatial effect of the digital economy on urban entrepreneurial competencies using the SDPDM. Furthermore, we build a TSDPM to further examine whether the impact of digital economy development on urban entrepreneurial competencies has a "threshold effect" with the regulation of the business environment, such as the market environment, legal environment, science and technology environment, financial environment, and policy environment. It is found that: (1) Both urban entrepreneurial competencies and the digital economy have obvious spatial dependence. (2) Whether in the long-term or short-term, the digital economy has an incentive effect on the improvement of local entrepreneurial competencies, but a negative effect on neighboring cities. Additionally, the long-term effect will be stronger than the short-term effect. (3) In different business environments, the impact of the digital economy on urban entrepreneurial competencies shows obvious non-linearity. Furthermore, there are significant threshold effects of business environments. In a better market environment, legal environment, science and technology environment, financial environment, and policy environment, the digital economy is better at infiltrating entrepreneurial activities, and plays a stronger role in improving urban entrepreneurial competencies.

Based on the above findings, this paper puts forward the following policy recommendations. First, the government should attach great importance to the role of digital economy development in promoting local entrepreneurial competencies. As a new economic model relying on emerging technologies such as the internet, blockchain, and artificial intelligence, the digital economy allocates resources efficiently and provides great incentives for local entrepreneurship. Relevant departments can enhance the application of digital technologies by strengthening precise training for entrepreneurs or those who may start businesses, in order to promote the transformation and upgrading of urban entrepreneurial

competencies and entrepreneurial quality in the context of the digital economy. Second, relevant departments should not only promote the interaction and integration of digital economy development among cities so as to form a joint force to promote the improvement of entrepreneurial competencies, but also adopt "city-specific policy" to formulate corresponding digital economy development plans based on the city's own characteristics and entrepreneurial environment in order to strengthen the incentive effect of the digital economy on local entrepreneurship. Third, a better business environment will optimize the relationship between the digital economy and urban entrepreneurial competencies. Relevant government departments should continuously improve external environments such as markets, science and technology, and policies, and build a better operating ecology for the digital economy to empower urban entrepreneurial competencies. Furthermore, the government should increase the support and protection of the new generation of information technology industries such as 5G, artificial intelligence, and industrial internet, promote the agglomeration of digital economy industries, and improve the activity and quality of regional entrepreneurship by agglomerating economic externalities.

This study still has some limitations and needs to be further explored in future studies. First of all, there are many factors in the business environment. Limited by space, this paper only considers five environmental factors. We can further explore the influence mechanism of other factors of the business environment—such as the cultural environment—on urban entrepreneurial competencies empowered by the digital economy in the future. Secondly, limited by the availability of data, the measurement and research of urban entrepreneurial competencies and the digital economy are still in the exploratory stage. There is no uniform standard for the measurement, which needs to be further optimized and improved.

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