Frontiers in Computing and Intelligent Systems
ISSN: 2832-6024 | Vol. 1, No. 1, 2022

The Digital Economy and the Regional Economic Gap: An Inverted U-shaped Relationship

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Abstract: As a new economic form, the digital economy is profoundly changing China, and clarifying the relationship between the digital economy and the regional economic gap is of great practical significance for coordinating regional economic development. Based on the perspective of new economic geography, the digital economy is incorporated into the core marginal model, and the impact of digital economy development on the change of regional economic gap under long-term equilibrium conditions is deduced Provincial panel data are used to support this. The study found that with the continuous development of the digital economy, the regional economic gap showed an inverted U-shaped trend of first expanding and then narrowing; Considering regional heterogeneity, the inverted U-shaped impact of the digital economy in the eastern, central and western regions on the regional economic gap is still obvious. Finally, this paper puts forward policy suggestions from the perspective of "the digital economy provides a solution to alleviate the imbalance and incongruity of regional development".

Keywords: Digital economy; Regional economic gap; Inverted U-shape; New economic geography.

1. Introduction

General Secretary Xi Jinping pointed out: "We must soberly realize that the problem of unbalanced and insufficient development in China is still relatively prominent, and the gap between urban and rural development, regional development and income distribution is relatively large. The new round of scientific and technological revolution and industrial transformation has given a strong impetus to economic development, but also has a profound impact on employment and income distribution, including some negative effects, which need to be effectively addressed and addressed [1]. "As a new economic form, the digital economy has been written into the government work report for the fifth time, which is profoundly changing China, becoming a new engine to enhance people's happiness and promote high-quality economic development, laying out a "digital picture" with a thousand meteorological conditions. However, whether the development of the digital economy can effectively alleviate the current "regional economic development imbalance" still needs theoretical explanations and empirical tests. Therefore, it is of great practical significance to comprehensively clarify the relationship between the digital economy and the regional economic gap for coordinating regional economic development.

Digital technologies based on information technologies such as artificial intelligence, big data, and cloud computing are developing rapidly and play a key role in production, circulation and other fields. Based on the perspective of spatial economics, the development of the digital economy, through the monetary externality of "saving production and transaction costs" and the technical externality of "knowledge spillover" improve the efficiency of information and knowledge exchange, and Continuously promote economic convergence [2], affecting regional economic disparities fluctuation .Regarding the monetary externalities of the development of the digital economy, at the micro level, digital technologies have general purpose technologies(GPT). All of these characteristics can improve the operational efficiency and business coverage radius of the enterprise, and reduce the marginal production cost of the enterprise, significantly improve the efficiency of product transportation. In the face of diversified and fragmented individual needs, the production management and marketing model of the "industrial era" is slow to respond and high in cost. Under the influence of the digital economy, the structure of the production system of enterprises has undergone qualitative changes, and the production system has been divided into universal modules and heterogeneous element modules. In other words, the combination of the basic public elements of the product together constitutes a universal module, and the heterogeneous elements of other products in addition to the public production factors are combined to efficiently produce differentiated products with different functions or the same function but different performance, so as to cope with the diversified market demand and complete the benign transformation of the production and marketing model to precision and refinement [3], so as to improve the production efficiency of enterprises, and effectively improve the efficiency of meeting the diverse needs of users. On the technological spillover effects of the digital economy, how to innovate in the context of responding to uncertainties and responding to diversified needs has become an inevitable problem for enterprises. Compared with the traditional closed-source innovation model, the open innovation model led by the digital age enables enterprises to maintain the acceptance of new ideas and good ideas at any time and place through the form of "crowdsourcing of R&D functions" [3], so as to continuously develop and innovate, reduce the average production cost.

As the general secretary said, the problem of regional economic gap in China has always existed, and from the existing literature and works, relevant scholars have explored from the perspective of digital economy development, but the results of studying the relationship between the two are relatively small. Based on the perspective of economic agglomeration, some scholars have found that with the development of the digital economy, the manufacturing industry has further concentrated, but at this stage it is not conducive to narrowing the regional gap [4]. Based on the perspective of labor factor allocation, some scholars have found that the digital economy has made the regional economic gap show an inverted U-shaped change characteristic through technological spillover and economic spillover effect [5]. The possible marginal contributions of this paper are: (1) to study the regional economic gap from the perspective of digital economy, and to explore the relationship between digital economy development and regional economic gap; (2) Incorporate the digital economy into the core-edge model from the perspective of influencing "production costs" and "transaction costs", and explore the relationship between the digital economy and the regional economic gap under long-term equilibrium conditions with the help of computer simulation technology. The remaining parts of this paper are arranged as follows: The second part, based on the CP model that introduces the effect of spatial congestion, explores the relationship between the level of digital economy and the regional economic gap; Part III, Empirical Strategies and Variable Selection; Part IV, reporting on estimates based on spatial metrology; Part V further discusses the impact of spatial congestion on regional economic disparities arising from the digital economy; Finally, there are conclusions and policy recommendations.

2. The Theoretical Analysis Framework: Logical Reasoning Based on Extended CP Model

2.1. Model derivation

2.1.1. Basic assumptions

Construct a general spatial equilibrium model of two regions, two departments, two elements 2×2×1. The two regions are represented by r=1, 2 respectively; The two sectors refer to agricultural sectors A and B, respectively, which are capable of trade in products, and the two regions meet the conditions of agricultural non-specialization, and agricultural production activities meet the general equilibrium of Walras, producing homogeneous agricultural products, without regard to their transaction costs, that is, the price of the product is the same in different regions. With regard to the non-agricultural sector, it is discussed under the framework of D-S monopolistic competition, in which each firm produces only one unit of a certain differentiated product. Set the consumer's consumption substitution flexibility for the differentiated products they face as σ. One unit of agricultural production requires only one unit of agricultural labor, and the wage is set to 1, but for each unit of non-agricultural products produced, it requires a fixed input of F units and a marginal input of MP units, both of which are measured in terms of the number of laborers and the yield function $L = F + MP \times q_{B(i)}$. With regard to transaction costs, it is assumed that the transport of products in the non-agricultural sector uses "iceberg transport costs", in T_B the sense of ($T_B > 1$). Agricultural labour does not choose to move across regions, accounting for 1/2 of each, while non-agricultural labour can move freely across regions; Because the share of agricultural labor force in each region is fixed, only the living space of non-agricultural labor force is considered, and with the increase of population density in a certain area, resource and environmental problems are prominent, traffic congestion, high housing prices and land prices and high production and living costs Problems gradually emerged. Referring to Pi Yabin(2016) modeling ideas, non-farm labor is subject to space congestion costs (only land rent and transportation costs are considered), taking area 1 as an example, space congestion cost C depends on the congestion coefficient η and labor shareS_B, specifically $C = \eta \cdot S_B / 2$ [6]. The remaining settings are basically the same as the CP model, and the differences are given as they are analyzed.

2.1.2. Short-term equilibrium

2.1.2.1. Consumer Conduct

The first layer of the consumer utility function, defined as the C-D type, is given by the invariant alternative elasticity (CES) utility function as follows:

$$\begin{cases} U = Q_A^{1-\mu} Q_B^{\mu} \\ Y = P_A Q_A + P_B Q_B + C \cdot I \end{cases} \quad (1)$$

Among them, Y is the income of consumers and all comes from wages, and there is no saving behavior; C refers to the cost of space congestion. $I = \begin{cases} 1, \text{Consumers are non}-\text{farm labour} \\ 0, \text{Consumers are agricultural labor} \end{cases}$; μ is the constant $(0 < \mu < 1)$,$1 - \mu$ andμ represents the consumer's share of spending on agricultural and non-agricultural products, respectively; Q_A and the quantitative indicators that represent the combination of Q_B agricultural products and non-agricultural products consumed by consumers, respectively, and use the constant substitution elastic utility function to represent non-agricultural products, that is $Q_B = \left[\int_{i=0}^{N_B} q_{B(i)}{}^{\sigma-1/\sigma} di\right]^{\sigma/\sigma-1}$, $q_{B(i)}$ the first The consumption of i products, σ which represents the amount between any two finished products Substitution elasticity and greater than 1, N_B indicating the range of types of products in the region; The non-agricultural price index $P_B = \left[\int_{i=0}^{N_B} p_{B(i)}{}^{\sigma-1/\sigma} di\right]^{\sigma/\sigma-1}$, $p_{B(i)}$ which is the price of the ith product.

According to the level of consumer utility maximization, the consumer demand function for agricultural and non-agricultural products is obtained:

$$Q_A = (1 - \mu)Y/P_A \quad (2)$$

$$Q_B = \mu Y/P_B \quad (3)$$

$$q_{B(i)} = \mu Y (p_{B(i)}^{-\sigma}/P_B^{1-\sigma}) \quad (4)$$

In addition, (2) and (3) are substituted into the consumer utility function, and the indirect utility function is obtained, and the area i complete price index is defined accordingly $G^i = (P_A^i)^{1-\mu}(P_B^i)^{\mu}$.

2.1.2.2. Producer behavior

The digital economy will have an impact on the production costs of enterprises. Digital procurement is the most effective means to solve the pain and difficulties of high procurement costs, difficult to find high-quality suppliers, scattered procurement needs, and cumbersome manual operations, helping enterprises to reduce their comprehensive costs by 12% [7]. The advent of the digital economy era has alleviated information asymmetry, reduced the cost of labor matching for enterprises, and provided a platform that can reduce labor sharing and learning costs [8]. In summary, the development of the digital economy will reduce the production costs of enterprises to a certain extent, drawing on the modeling ideas of An Tongliang (2020) to define the production cost function $COST = \frac{w_B}{\theta}(F + MP \cdot q_{B(i)})$, which w_B refers to the wage level of non-agricultural labor. The meaning of the formula is: the level of digital economy development (θ)increase, will reduce the original production costs of enterprises $w_B(F +$

$MP \cdot q_{B(i)}$), and assume that the cost reduction effect of the digital economy in enterprises in the two regions is comparable.

According to the given cost function, the profit function of the products produced by the representative enterprises of the easy to obtain non-agricultural enterprises i:

$$\pi_i = p_i q_{B(i)} - \frac{w_B}{\theta}(F + MP \cdot q_{B(i)}) \quad (5)$$

Combined with equation (4), according to the conditions of profit maximization, the product price function is obtained, and the product price is found to be irrelevant to the type, and the product type i can be omitted:

$$p_B = \frac{\sigma}{\sigma-1}\frac{w_B}{\theta} MP \quad (6)$$

It should be noted that although we are discussing under the framework of D-S monopoly competition, enterprises are facing a market that belongs to a perfectly competitive market, and the pricing strategy of enterprises can be set as a bonus pricing method, and the formula (6) is brought into the formula (5) to obtain the output of the enterprise $q_B = \frac{F(\sigma-1)}{MP}$. It was also found to be independent of the species. Further bringing the output of enterprises into the production function, the number of enterprises is obtained $N_B = \frac{L_B}{F\sigma}$, and there are two regional shares of enterprises engaged in non-agricultural production in zone 1, $\lambda = S_B$, S_B referring to zone 1 Share of the total non-farm labour force.

2.1.2.3. Wage level determination

For the following analysis to be simple, some standardization is required before subsequent derivation. First determine the market size of each region, the total expenditure of easy-to-get areas 1 and 2 is:

$$\begin{cases} E^1 = \frac{1}{2}(1-\mu) + \lambda\mu(w_B^1 - \eta S_B/2) \\ E^2 = \frac{1}{2}(1-\mu) + (1-\lambda)\,\mu[w_B^2 - \eta(1-S_B)/2] \end{cases} \quad (7)$$

It should be clear that digital technology can effectively reduce the external transaction costs of enterprises, on the one hand, the reduction of search costs, the reduction of costs such as negotiation and negotiation between enterprises, and the flexibility of transaction details can avoid unpredictable costs [9]. On the other hand, with the digital economy, the emergence of new logistics models, the rapid development of the express delivery industry, and the transportation cost curve will gradually decline [2]. To this end, the introduction of digital technology into the transaction level, set δ to the level of digital economy development at the transaction cost level, the range of "iceberg transportation costs" is $\frac{T_B}{\delta}$, and $1 < \delta < T_B$.

According to formula (6), combined with the premise of transportation costs, for the non-agricultural sector, the selling prices of enterprises in areas 1 and 2 of zone 1 are: respectively $p_B^{11} = \frac{w_B^1}{\theta}$, $p_B^{12} = \frac{T_B}{\delta}\frac{w_B^1}{\theta}$. Similarly, it can be known that the selling prices of products of enterprises in Area 1 and 2 are as follows $p_B^{21} = \frac{T_B}{\delta}\frac{w_B^2}{\theta}$, $p_B^{22} = \frac{w_B^2}{\theta}$: Where θ the level of digital economy development at the level of production costs is met $\theta \geq 1$; δ is the level of digital economy development at the level of transaction costs in the range. Based on the above analysis, the price function of non-agricultural sector enterprises is easy to obtain. At the same time, according to the definition of the price index, the tradable non-agricultural products price index of each region is obtained:

$$\begin{cases} P_B^1 = \left[\lambda\left(\frac{w_B^1}{\theta}\right)^{1-\sigma} + (1-\lambda)\left(\frac{T_B w_B^2}{\delta\theta}\right)^{1-\sigma}\right]^{1/1-\sigma} \\ P_B^2 = \left[\lambda\left(\frac{T_B w_B^1}{\delta\theta}\right)^{1-\sigma} + (1-\lambda)\left(\frac{w_B^2}{\theta}\right)^{1-\sigma}\right]^{1/1-\sigma} \end{cases} \quad (8)$$

In order to meet the market clearance conditions for tradable non-agricultural products, all the output of the enterprise needs to be sold out in two regions, so the sales volume $\Lambda_B^1 = p_B q_B = p_B^{11} q_B^{11} + p_B^{12} q_B^{12}$, wherein the q_B^{11}, q_B^{12} non-agricultural enterprises located in Zone 1, are located in Zone 1 and Zone 2, respectively. Combined formula (4), formula (6) ~ (8), the price of the product in each region p_B^{11}, p_B^{12} and standardized conditions, Sales of enterprises in Available Zone 1:

$$\Lambda_B^1 = \mu\left(\frac{w_B^1}{\theta}\right)^{1-\sigma}\left[E^1(P_B^1)^{\sigma-1} + \left(\frac{T_B}{\delta}\right)^{1-\sigma} E^2(P_B^2)^{\sigma-1}\right] \quad (9)$$

Similarly, sales of Region 2 companies:

$$\Lambda_B^2 = \mu\left(\frac{w_B^2}{\theta}\right)^{1-\sigma}\left[\left(\frac{T_B}{\delta}\right)^{1-\sigma} E^1(P_B^1)^{\sigma-1} + E^2(P_B^2)^{\sigma-1}\right] \quad (10)$$

Suppose that the enterprise produces under the condition of zero profit, so the income of the enterprise is the remuneration of the labor force, that is $\Lambda_B = w_B L_B$. In summary, get the expression of wage levels for non-farm labor in zones 1 and 2:

$$\begin{cases} w_B^1 = \left(\frac{1}{\theta}\right)^{\frac{1-\sigma}{\sigma}}\left[E^1(P_B^1)^{\sigma-1} + \left(\frac{T_B}{\delta}\right)^{1-\sigma} E^2(P_B^2)^{\sigma-1}\right]^{\frac{1}{\sigma}} \\ w_B^2 = \left(\frac{1}{\theta}\right)^{\frac{1-\sigma}{\sigma}}\left[\left(\frac{T_B}{\delta}\right)^{1-\sigma} E^1(P_B^1)^{\sigma-1} + E^2(P_B^2)^{\sigma-1}\right]^{\frac{1}{\sigma}} \end{cases} \quad (11)$$

2.1.3. Long-term equilibrium

Through short-term equilibrium analysis, the wage level of labor under static conditions can be determined. According to the previous deduction, the spatial distribution of satisfying labor is equivalent to the spatial distribution of enterprises, so under the influence of the digital economy, the spatial distribution of economic activities λ is the key to identifying long-term steady-state equilibrium. Assuming that unemployment does not exist within each region, labour mobility decisions are based on the level of utility actually obtained. Thus, the equation for the spatial mobility of labor can be expressed as:

$$\dot{\lambda} = \lambda(1-\lambda)\left(\frac{\Omega_1}{\Omega_2} - 1\right) \quad (12)$$

Among $\Omega_1 = \frac{w_B^1 - \eta S_B/2}{G^1}$, $\Omega_2 = \frac{w_B^2 - \eta(1-S_B)/2}{G^2}$ them, the actual level of utility obtained by employment labor in the non-farm sector in Regions 1 and 2, respectively; G^1, G^2 respectively, the two regions face the full price index for residents $G^i = (P_A^i)^{1-\mu}(P_B^i)^{\mu}$ $(i = 1, 2)$.

2.1.4. Calculation of regional output per capita

The model assumes that tradable products have been cleared from the market, and that the output of the sector is converted into household consumption expenditure, except for part of the cost of space congestion. According to Formula (7), combined with standardized conditions, the total output of residents in area 1 is obtained (total expenditure + cost of space congestion):

$$GDP^1 = \frac{1}{2}(1-\mu) + \lambda\mu w_B^1 \quad (13)$$

The total population of region 1 is $\frac{1}{2}(1-\mu) + \lambda\mu$. Based on formula (13), the full price index and the total population of the region, the real output per capita of the region 1 is obtained:

$$PCG^1 = \frac{\frac{1}{2}(1-\mu) + \lambda\mu w_B^1}{\frac{1}{2}(1-\mu) + \lambda\mu}\frac{1}{G^1} \quad (14)$$

Similarly, the 2 per capita output of the Easy Know region:

$$PCG^2 = \frac{\frac{1}{2}(1-\mu)+(1-\lambda)\mu w_B^2}{\frac{1}{2}(1-\mu)+(1-\lambda)\ \mu} \frac{1}{G^2} \tag{15}$$

At this point, it is not difficult to find that ${PCG^1}/{PCG^2}$ regional economic disparities can be measured. The indicator is close to 1, which can be considered to be a small regional economic gap; ${PCG^1}/{PCG^2}$ away from 1, the greater the regional gap.

2.2. Numerical simulation

In view of the difficulty of examining the analytical form of the model under the long-term equilibrium situation, the numerical simulation is carried out with the help of Matlab software. The definition describes the spatial distribution curve of economic activity as curve A, and the curve of describing regional economic gap as curve B. The vertical axis of the image represents the actual utility gap Ω_1/Ω_2 and the regional economic gap PCG^1/PCG^2, and the horizontal axis represents the spatial distribution status of enterprises (λ). The two forces that affect the equilibrium state of enterprise site selection are: the agglomeration force based on the market proximity effect and the cost of living effect; Dispersive forces based on local competitive effects and space congestion costs. Digital technology has an impact on the system of two forces, and through the endogenous mechanism of enterprise transfer (labor mobility), the internal two forces are re-balanced, affecting the spatial distribution of enterprises. The process of reaching homeostasis again by externally influenced systems is more complicated, and we only focus on two signals for enterprise transfer to reach steady state: (1) The internal equilibrium solution of incomplete agglomeration: ${\Omega_1}/{\Omega_2}=1$ satisfied $\frac{\partial(\Omega_1/\Omega_2)}{\partial\lambda}<0$; (2) Corner point solution: ${\Omega_1}/{\Omega_2}=1$ satisfied at the place $\frac{\partial(\Omega_1/\Omega_2)}{\partial\lambda}>0$.

First, the common state parameter is set μ=0.4, σ=5.0, $\eta=0.1$, $T_B=1.8$; Then, assuming that the digital economies of the two regions develop simultaneously, the digital technology levels of regions 1 and 2 can be assigned, respectively: the lower level (δ,θ) =(1.1, 1.1); Moderate level (δ,θ) =(1.4, 1.4); Higher levels (δ,θ) =(1.7, 1.7). It will be traversed$\lambda$from 0 to 1 to simulate that under the influence of different digital technology levels, the transfer of enterprises in area 1 is in a spatially balanced distribution state λ.

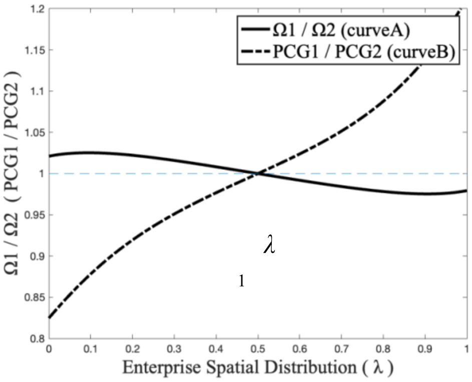

Figure 1. Lower level

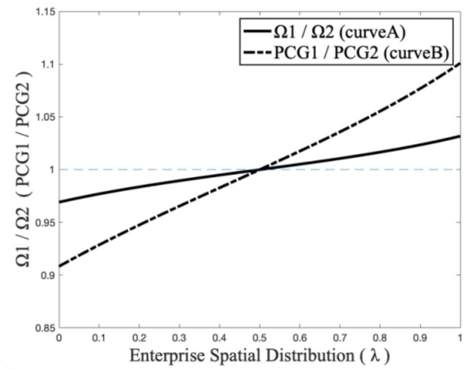

Figure 2. Medium level

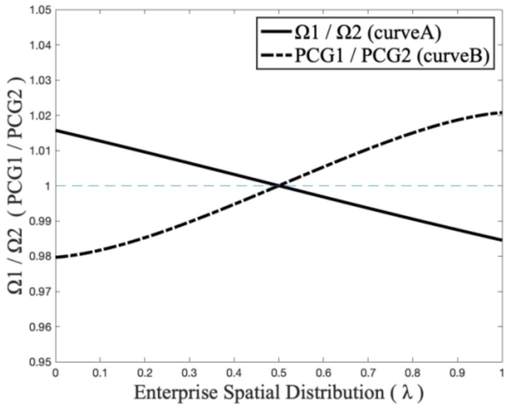

Figure 3. Higher level

From the simulation results of Figure 1.1, it can be seen that digital technology has just started, and it $\left.\frac{\partial(\Omega_1/\Omega_2)}{\partial\lambda}\right|_{\lambda=\lambda_1}<0$ is satisfied that the$\lambda_1$spatial distribution is in a steady state, the symmetrical equilibrium is still stable, and the enterprise site selection tends to be symmetrical. Observing curve B, it is found that the regional economic gap PCG^1/PCG^2tends to 1, which can be considered that the initial stage of digital technology has not had a significant impact on the regional gap; As shown in Figure 1.2, with the gradual development of digital technology in zone 1 to the medium level $\left.\frac{\partial(\Omega_1/\Omega_2)}{\partial\lambda}\right|_{\lambda=\lambda_2}>0$, the symmetrical structure has obviously become unstable, and there is a tendency for non-agricultural enterprises to concentrate in a certain area. Looking at curve B again, the $\lambda_2$disturbance of the shift of enterprises to the north is applied to the point, and it is found that PCG^1/PCG^2gradually moving away from 1, it can be considered that the regional gap may be widened in the medium term of the development of digital technology; Figure 1.3 illustrates the influence of higher digital technology levels,$\left.\frac{\partial(\Omega_1/\Omega_2)}{\partial\lambda}\right|_{\lambda=\lambda_3}<0$symmetrical equilibrium from unstable to stable, and PCG^1/PCG^2tends to 1, it can be said that with the high development of digital technology, regional disparities show a narrowing trend.

Proposition: In the real world, the relationship between the digital economy and the regional economic gap is non-linear, that is, with the continuous development of the digital economy, the regional economic gap shows an inverted U-shaped trend of first expanding and then narrowing.

3. Empirical Strategies and Variable Selection

3.1. Empirical strategies

Numerical simulation results show that the impact of digital economy on regional economic gap may show an inverted U-shaped relationship, that is, in the early stage of digital technology development, with the development of digital technology, the regional economic gap is significantly widened. However, once the level of digital technology crosses a certain threshold, the economic gap between regions will tend to narrow. In order to study such non-monotonicity, Xu Lifang's (2017) approach was drawn to add the square term of the digital economic development level to the regression model [10]. Therefore, consider the double fixed effect traditional panel regression model as follows. When $\alpha_1 > 0$, $\alpha_2 < 0$, it can be preliminarily determined that the gap between the digital economy and the regional economy is inverted U-shaped.

$$\mathrm{GAP}_{i;t} = \alpha_0 + \alpha_1 \mathrm{DEI}_{i;t} + \alpha_2 \mathrm{DEI}_{i;t}^2 + \alpha_3 \mathrm{Control}_{i;t} + \mu_i + \kappa_t + \varepsilon_{i;t} \quad (16)$$

Among them, $\mathrm{GAP}_{i;t}$ the level of regional economic gap representing the t-time region i; $\mathrm{DEI}_{i;t}$ represents the level of digital economy development of the t-time region i; $\mathrm{DEI}_{i;t}^2$ represents its square term; $\mathrm{Control}_{i;t}$ is a set of control variables; μ_i refers to the fixed effect of each provincial region; κ_t represents the fixed effect of the year; $\varepsilon_{i;t}$ is a random perturbation term.

Regional economic gap is a dynamic concept, not only with the region's own conditions change, but also affected by external conditions, in addition, the economic and social relations between neighboring regions are objectively existing, the impact on the local regional economic gap cannot be ignored, the introduction of spatial effects into the empirical model can maximize the persuasiveness of model conclusions. To this end, the spatial panel model is established as follows to verify the inverted U-shaped relationship between the digital economy and the regional economic gap.

Moran' I index and local Moran scatter plot are used to test whether the spatial factors introduced into the panel model are reasonable. Further, according to the LM test, Robust-LM test, LR test and Robust-LR test, a spatial panel model suitable for the object of study in this paper can be selected. According to the impact mode of the space term, the model is as follows:

$$\mathrm{GAP}_{i;t} = \beta_0 + \mathrm{rho} \cdot W^G \cdot \mathrm{GAP}_{i;t} + \beta_1 \mathrm{DEI}_{i;t} + \beta_2 \mathrm{DEI}_{i;t}^2 + \beta_3 \mathrm{Control}_{i;t} + \mu_i + \kappa_t + \varepsilon_{i;t}$$
$$\varepsilon_{i;t} = \lambda W^G \varepsilon_{i;t} + \xi_{i;t} \quad (17)$$

Where, W^G for the spatial geographic weights matrix; rhois the spatial hysteresis coefficient; $\lambda$is the number of autoregressive systems for spatial error. When$\lambda = 0$, $rho \neq 0$ the spatial panel model is a spatial lag model (SAR); When $\lambda \neq 0$, $rho = 0$, the spatial panel model is a spatial error model (SEM).

For the spatial econometric model constructed above, since the regional economic gap is introduced as an explanatory variable as a first-order lag term, problems related to the random error term may arise, and it is particularly important to choose an appropriate estimation method. In this paper, the maximum likelihood estimation method MLE suitable for spatial panel models is used to estimate the parameters of the model. It is worth noting that some factors and variable measurement errors missing from the model may seriously affect the ability of the digital economy level to interpret the interpreted variables, for this reason, all metrology models in this paper use robust standard errors to eliminate the influence of heteroscedasticity on coefficient estimation.

3.2. Variable selection

3.2.1. Interpreted variables

Regional Economic Gap (GAP). How to describe regional economic disparities is a thorny issue, and some studies have used economic indicators such as per capita GDP and per capita GDP growth rate to measure inter-regional economic disparities, but I believe that this approach does not reflect the disparities in the model. This paper synthesizes the measurement method of Lu Hongyou (2012) [11] and BianYuanchao (2018) [12] to measure regional gap, and selects the logarithm of per capita GDP in each provincial-level region the difference from the logarithm of gdp per capita in the country. The time span of per capita GDP is from 2011 to 2019, and the per capita GDP in all years is based on 2010, according to the per capita of each provincial region The GDP Reduction Index is smoothed out to calculate comparable variable values for each year.

3.2.2. Core explanatory variables

Table 1. Measurement index system for the level of digital economy development

Level 1 indicators	Secondary indicators	Metric measurement method	Attribute
Digital economy Development Index	Internet penetration	Number of Internet broadband access users per 100 people	+
	Number of Internet-related practitioners	Computer service and software employees account for the proportion of employed personnel in urban units (%)	+
	Internet-related outputs	Total telecommunications services per capita	+
	Number of mobile Internet users	Number of mobile phone subscribers per 100 people (%)	+
	Inclusive development of digital finance	China Digital Financial Inclusion Index	+

Digital Economy Development Index (DEI). For the sake of data availability, drawing on the practice of Zhao Tao (2020) [13], the five indicator sets of the digital economy development level of different provinces (2011-2019) are used Take measurements. The index is based on Internet penetration, the number of Internet-related practitioners, Internet-related output, the number of mobile Internet users, and the inclusive development of digital finance, and the specific measurement methods are shown in Table 1. For the dimensionality reduction treatment of the data of 5 indicators, we use the method of principal component analysis. The indicator covers a wide range of socio-economic content, captures the industry penetration of digital technology, and more accurately conforms to the definition of the digital economy in the economic community.

3.2.3. Control variables

In order to prevent the influence of other factors on the empirical results of this paper, with reference to the relevant domestic literature, the following control variables are selected, and the time span is 2011-2019, including: (1) the development level of the tertiary industry (TIS). Measured by tertiary industry output value/regional GDP of each region; (2) Human capital level (SH). Human capital is a decisive factor in the region's long-term economic growth, plays an important role in a sustainable economy, and is also a non-negligible part of the regional economic gap. There are many ways to measure the stock of human capital, and this paper proposes to use the average number of years of education to measure, that is, SH=6 a_1 +9 a_2 +12 a_3 +16 a_4 , a_1, a_2, a_3, a_4 which indicates that the number of primary school culture, primary Chinese, high Chinese and college education in each provincial-level area accounts for the proportion of the permanent population; (3) Level of public expenditure (GY). The level of government public expenditure measures the government's contribution to the people's livelihood such as education and health, and is measured in terms of regional government general public budget expenditure/regional GDP; (4) Level of opening to the outside world (FE). The intensity of foreign trade dependence is an important source of economic growth, which is expressed by the import and export trade volume (RMB) of each region as the regional GDP. (5) Foreign Investment Level (TI). The year-end registered foreign investment amount (RMB) / regional GDP measurement of each region is selected.

3.3. Data sources and descriptive statistics

Table 2. Descriptive statistics for variables

Variable	Symbol	Observations	Mean	SD	Min	Max
Regionaleconomicdisparities	GAP	270	-0.016	0.391	-0.808	0.911
Digital economy	DEI	270	0.290	0.166	0.016	0.911
Tertiary industry development	TIS	270	0.486	0.090	0.327	0.837
Human capital	SH	270	0.188	0.099	0.080	0.622
Level of public spending	GY	270	1.253	0.584	0.453	3.468
The level of opening up to the outside world	FE	270	0.279	0.297	0.013	1.464
Levelofforeigninvestment	TI	270	0.384	0.365	0.048	1.735

This paper uses annual data modeling to collect panel data from 2011 to 2019 from 30 provincial-level administrative units in China (due to the lack of some data, not considering Tibet, Hong Kong, Macao and Taiwan). Statistical Yearbook", "Statistical Yearbook of Chinese and Employment", "Peking University Digital Inclusive Finance Index" and "China Trade and Foreign Economic Statistics Yearbook". According to the search data, it is possible to explore the role of digital economy, economy and other factors on regional economic disparities. The descriptive statistics of variables are shown in Table 2.

4. Empirical Analysis: Verification based on spatial metrology

4.1. Spatial autocorrelation test

To determine whether spatial factors are introduced, a spatial autocorrelation test was performed on the level of economic difference in each region using the global Moran' I test based on the cross-sectional data perspective, and the results are reported in Table 3. The results show that we are 99% sure that the level of regional economic gap is contiguous and agglomeration at the spatial level, which verifies that there is a significant spatial dependence of regional economic gap, and it is necessary to adopt spatial panel regression methods for the subsequent inverted U-shaped impact of the digital economy on the regional economic gap.

Table 3. Global Moran test results

	Geographical distance				
year	Moran value	Z value	year	Moran value	Z value
2011	0.377***	4.336	2016	0.362***	4.160
2012	0.376***	4.318	2017	0.361***	4.153
2013	0.371***	4.262	2018	0.361***	4.158
2014	0.365***	4.202	2019	0.363***	4.187
2015	0.362***	4.162			

Note: "***, **, *" indicates that it has passed the significance test at the levels of 1%, 5%, and 10%, respectively.

4.2. Benchmark regression

The two types of non-observed effects of province and year effects are controlled differently, and the traditional panel model of double fixed effects is used, and the regression results are shown in the columns of table 4 (1), (2). Further, regional economic disparities exist spatially dependent, while L M tests, Robust LM tests also show the rationality of using spatial panel models, and therefore, in tables Columns (3)~(6) of 4 list the estimated results of the spatial lag model and the spatial error model.

The empirical results show that compared with the traditional panel model under the same fixed effect, the level coefficient of digital economy development is at least 10% significant, and the square term estimation coefficient is significant at the 1% level, which confirms the proposition "nonlinear inverted U of the gap between the digital economy and the regional economy." type relationship". Compared with the spatial panel model under the same fixed effect, the coefficients of the primary and secondary terms of the digital economy development level are at least at least 10%, and the coefficient symbol satisfies the inverted U-shape condition. It can be considered that the inverted U-shaped relationship between the digital economy and the regional economic gap is still established under the consideration of spatial factors. The reason is that the gradual improvement of the level of digital economy development in a certain region may lead to the improvement of the level of enterprise industrial agglomeration, entering a virtuous circle of "agglomeration-optimization-re-agglomeration", which is in stark contrast to the vicious cycle of "loss-deterioration-re-loss" in peripheral areas, causing regional economic gaps; When digital technology is further developed, the agglomeration power of enterprises in the region becomes weaker, and the effect of spatial congestion gradually appears, which, together with the competition effect of local market in the region, jointly affects the location choice of enterprises and causes regional gaps to converge. The spatial term coefficient rho value of the SAR model is significantly positive at least 1%, indicating that there is a positive spillover effect on the regional economic gap in China. The spatial term coefficient λ of the SEM model is significantly positive at least at least 1%, indicating that there is an omission in the selection of control variables in this paper, and the spatial autocorrelation may be achieved by the error term, although the digital economy is inverted to the regional gap. The type relationship is still significant, revealing the correctness of the proposition.

Table 4. Benchmark regression results

variable	(1)	(2)	(3)	(4)	(5)	(6)
	FE		SAR		SEM	
Main						
DEI	0.528***	0.773***	0.324***	0.452**	0.468***	0.554**
	(0.116)	(0.250)	(0.102)	(0.217)	(0.139)	(0.238)
DEI^2	-0.496***	-0.442***	-0.316***	-0.328**	-0.443***	-0.449***
	(0.108)	(0.155)	(0.099)	(0.151)	(0.136)	(0.159)
TIS	-0.424**	-0.407*	-0.386**	-0.429**	-0.422***	-0.416***
	(0.194)	(0.215)	(0.162)	(0.169)	(0.149)	(0.150)
SH	-0.387**	-0.519***	-0.299**	-0.388***	-0.319**	-0.340**
	(0.151)	(0.174)	(0.123)	(0.142)	(0.142)	(0.143)
GY	0.087***	0.081***	0.079***	0.075***	0.084***	0.085***
	(0.018)	(0.026)	(0.018)	(0.024)	(0.016)	(0.021)
FE	0.090	0.132**	0.109**	0.116*	0.111*	0.120**
	(0.054)	(0.058)	(0.055)	(0.060)	(0.057)	(0.058)
TI	-0.066***	-0.054**	-0.051***	-0.052**	-0.048**	-0.046**
	(0.024)	(0.025)	(0.020)	(0.021)	(0.020)	(0.020)
Spatial						
rho			0.588***	0.541***		
			(0.079)	(0.090)		
λ					0.702***	0.637***
					(0.074)	(0.089)
Sample size	270	270	270	270	270	270
The province is fixed	Yes	Yes	Yes	Yes	Yes	Yes
The year is fixed	No	Yes	No	Yes	No	Yes
Log-L	—	—	672.9	681.9	670.2	143.4
R^2	0.604	0.656	0.558	0.513	0.601	0.557

Note: "***, **, *" indicates that it has passed the significance test at the level of 1%, 5% and 10% respectively; Robust standard errors are in parentheses. The same applies below.

Regarding the control variables, under the regional fixed and double fixed models, increasing the proportion of the tertiary industry in regional GDP and increasing the level of regional human capital can significantly narrow the regional economic gap, because the industrial structure and human capital are important links between economic activities, and play an important role in optimizing the allocation of factor resources, improving technological efficiency, and enhancing the ability to match modern industries, thereby curbing the trend of widening regional economic gaps; Improving the level of foreign investment has to a certain extent made up for the shortage of funds in development, brought a large number of jobs and taxes, improved the level of regional economic development, and narrowed the regional economic gap. Government public spending and opening up will significantly widen regional economic disparities and will be analyzed in detail when the sample returns later.

4.3. Robustness testing

In order to verify the reliability of the inverted U-shape, this paper replaces the measure of regional economic gap from the perspective of variables, and selects the difference between the logarithm of per capita disposable income of residents in each provincial-level region and the national level. Columns 5 (13) to (15) of Table 5 report the estimation results of replacing the explanatory variables, and the primary term coefficients of the digital economy are significantly positive and the secondary term coefficients are significantly negative, which satisfies the conditions of the inverted U-shaped relationship, which shows that the estimation results are basically consistent with the above conclusions. Next, the economic distance weight matrix is replaced, and the inverted U-shape is further tested using the spatial lag double fixed effect model, columns (16), (17). Estimates have been reported and remain consistent with the conclusions above. It is worth noting that the coefficient of spatial lag terms under the economic weight's matrix does not correspond to the preceding paragraph, but does not affect the conclusion of this article, because the rho value does not accurately refer to the spatial spillover effect of the digital economy on economic disparities.

Table 5. Robustness test results

variable	Replace the interpreted variable			Replace the spatial weight matrix	
	(13)	(14)	(15)	(16)	(17)
	FE	*SAR*	*SAR*	W^E	W^E
Main					
DEI	0.717***	0.388***	0.406***	0.927***	0.704***
	(0.140)	(0.150)	(0.115)	(0.293)	(0.205)
DEI^2	-0.292***	-0.181**	-0.168**	-0.600***	-0.452***
	(0.0595)	(0.0915)	(0.0719)	(0.151)	(0.141)
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled
Spatial					
rho		0.749***	0.677***	-0.492***	-0.666***
		(0.0847)	(0.115)	(0.133)	(0.120)
Sample size	270	270	270	270	270
Fixed province/ year	Y/Y	Y/Y	Y/Y	Y/Y	Y/Y
Log-L		801.9	849.1	604.3	678.3
R^2	0.538	0.013	0.025	0.325	0.600

4.4. Regional heterogeneity analysis

The previous article clarified that the regional economic gap shows a non-linear trend of first expanding and then narrowing with the development of the digital economy. In order to ensure the reliability of the estimated results and consider the influence of regional heterogeneity on the invertedU-shaped relationship, this paper will "re-test" the inverted U-shaped trendfrom the sample segmentation method. Table 6 is the result of the spatial SAR estimation of the three major regions of eastern, central and western China.

The results show that with regard to the eastern sample, whether it is a fixed effect in the controlled area, an annual fixed effect, or a double fixed effect, the inverted U-shaped effect of the digital economy on the regional economic gap is at least significant at the level of 10%. In the central sample, under the fixed effect and double fixed effect of the control area, the primary and secondary term coefficients of the digital economy development level were at least significant at the level of 5%, while after the fixed effect of the control time, the secondary term of the digital economy level was not significant; Regarding the western sample, from a statistical point of view, the inverted U-shaped relationship between the fixed effect of the controlled area and the fixed effect of time is more significant, and the coefficient symbol is consistent with the regression result of the whole sample, which verifies the inverted U-shaped relationship between the digital economy and the regional economic gap. The inverted U-shaped relationship under the double fixed effect is not significant. The reason for the above estimates is that, on the one hand, the development of the digital economy in various regions is unbalanced and uncoordinated, and there is a "digital divide" between regions; On the other hand, some underdeveloped areas may be constrained by multiple factors such as geographical conditions, factor endowments, industrial supporting capabilities, and technical levels, and it is not easy to form a strong market proximity effect and cost of living effect, resulting in difficulties in cultivating local leading industries, weak endogenous development capabilities, and gradual economic development gaps Be pulled. Regarding control variables, changes in the level of government public expenditure in different regions will have a heterogeneous effect. The increase in the level of government public expenditure in the eastern and central regions will widen the regional economic gap; The increase in the level of expenditure in the western region will significantly narrow the regional economic gap. Therefore, as a fiscal policy that coordinates horizontal imbalances between regions, central transfer payments play an important role in narrowing the gap in regional economic development. Therefore, it is necessary to continue to deepen the cooperation and joint construction between the eastern and central and western regions, promote the development of open and high-quality development along the border, promote the acceleration of the formation of an open pattern of land and sea linkage, and mutual assistance between the east and the west, so as to alleviate the regional economic gap.

Table 6. Fixed effect regression results of sub-sample space panel based on SAR model

variable	Eastern region		Central Region		Western region	
	(7)	(8)	(9)	(10)	(11)	(12)
Main						
DEI	0.346***	0.551**	0.479**	1.710***	0.919***	0.558
	(0.119)	(0.238)	(0.225)	(0.504)	(0.241)	(0.458)
DEI^2	-0.306***	-0.377***	-0.568***	-1.664***	-0.957***	-0.276
	(0.0865)	(0.120)	(0.218)	(0.620)	(0.230)	(0.487)
Control variables	Controlled	Controlled	Controlled	Controlled	Controlled	Controlled
Spatial						
rho	-0.359***	-0.461***	0.456***	0.348**	0.326**	0.146
	(0.0753)	(0.0729)	(0.124)	(0.157)	(0.161)	(0.217)
Sample size	99	99	81	81	90	90
Fixed province/year	Y/N	Y/Y	Y/N	Y/Y	Y/N	Y/Y
Log-L	262.0	286.5	212.3	238.3	220.0	229.9
R^2	0.427	0.257	0.686	0.471	0.744	0.002

The results show that with regard to the eastern sample, whether it is a fixed effect in the controlled area, an annual fixed effect, or a double fixed effect, the inverted U-shaped effect of the digital economy on the regional economic gap is at least significant at the level of 10%. In the central sample, under the fixed effect and double fixed effect of the control area, the primary and secondary term coefficients of the digital economy development level were at least significant at the level of 5%, while after the fixed effect of the control time, the secondary term of the digital economy level was not significant; Regarding the western sample, from a statistical point of view, the inverted U-shaped relationship between the fixed effect of the controlled area and the fixed effect of time is more significant, and the coefficient symbol is consistent with the regression result of the whole sample, which verifies the inverted U-shaped relationship between the digital economy and the regional economic gap. The inverted U-shaped relationship under the double fixed effect is not significant. The reason for the above estimates is that, on the one hand, the development of the digital economy in various regions is unbalanced and uncoordinated, and there is a "digital divide" between regions; On the other hand, some underdeveloped areas may be constrained by multiple factors such as geographical conditions, factor endowments, industrial supporting capabilities, and technical levels, and it is not easy to form a strong market proximity effect and cost of living effect, resulting in difficulties in cultivating local leading industries, weak endogenous development capabilities, and gradual economic development gaps Be pulled. Regarding control variables, changes in the level of government public expenditure in different regions will have a heterogeneous effect. The increase in the level of government public expenditure in the eastern and central regions will widen the regional economic gap; The increase in the level of expenditure in the western region will significantly narrow the regional economic gap. Therefore, as a fiscal policy that coordinates horizontal imbalances between regions, central transfer payments play an important role in narrowing the gap in regional economic development. Therefore, it is necessary to continue to deepen the cooperation and joint construction between the eastern and central and western regions, promote the development of open and high-quality development along the border, promote the acceleration of the formation of an open pattern of land and sea linkage, and mutual assistance between the east and the west, so as to alleviate the regional economic gap.

5. Conclusions and recommendations

5.1. Conclusions of the study

This paper attempts to explore the trend of the digital economy affecting the changes in regional economic gaps from the perspective of new economic geography. The main conclusion is that :(1) The digital economy profoundly affects the behavior of consumers and producers. Overall, with the continuous development of the digital economy, the regional economic gap shows an inverted U-shaped trend of first expanding and then narrowing. From the perspective of heterogeneous regions, the inverted U-shaped relationship between the level of digital economy development in the eastern, central and western regions and the regional economic gap is still significant. (2) In the low-level stage of the digital economy, the effect of the digital economy on the regional economic gap is a positive effect, and a higher degree of congestion will promote this positive effect. At the high level of the digital economy, the digital economy rises to a negative effect on regional economic disparities, and space congestion will strengthen this negative effect. (3) Extremely developed areas such as Beijing and Shanghai benefit from the digital economy, and higher levels of agglomeration may occur, opening up the economic gap with other regions.

5.2. Policy recommendations

This article does not negate agglomeration, but agrees with the fact that agglomeration of economic factors improves production efficiency. However, the author is more concerned about the subsequent development of areas with weak agglomeration in the context of the digital economy, or what impact the development of the digital economy will have on the changes in the regional economic gap. Therefore, while promoting higher levels of agglomeration in developed areas, it is even more necessary to find a way out for underdeveloped areas, especially in declining areas. To this end, this paper proposes: (1) The digital economy provides a solution to alleviate the imbalance of regional development. Continuously become bigger, stronger and better china's digital economy, promote the deep integration of digital technology and enterprises, and give play to the "picking beams" function of the digital economy in stable growth and development. Taking this important opportunity to increase investment in underdeveloped areas in the form of "new infrastructure", so that underdeveloped areas can catch the "digital economy +" free ride Explore unique advantageous endowments from the local area, such as geographical comparative advantages, natural resource endowments, cultural conditions, good market competition environment and high-quality local government services, etc., seize the historic opportunity of industrial transfer in the eastern region, cultivate regional leading industries, expand local market potential, cross the inflection point of the inverting U,, and narrow the regional economic gap. (2) Highly developed areas should rely on digital technology to digitize and network the spatial behavior of production and life, connect factor resources, improve the business environment of enterprises, optimize the allocation of resources, land and other elements, alleviate environmental and traffic pressures, and reduce production and living costs Promote the construction of smart communities and digital health services, improve the quality of residents after birth, properly cope with a series of negative impacts caused by excessive agglomeration of factors, lead to higher levels of agglomeration, and promote high-quality economic development.

References

[1] Xi Jinping. Solidly promoting common prosperity [J]. Qiushi, 2021(20): 4-8.

[2] Wang Ruyu, Liang Qi, Li Guangqian. Virtual Agglomeration: A New Form of Spatial Organization with Deep Integration of New Generation Information Technology and Real Economy [J].Management World, 2018, 34(02):13-21.

[3] Qi Yudong, Xiao Xu. Enterprise Management Reform in the Era of Digital Economy [J].Management World, 2020,36(06):135-152+250.

[4] Duan Bo, Shao Chuanlin, Duan Bo. Has the digital economy exacerbated regional disparities? Empirical evidence from 284 prefecture-level cities in China [J].World Geographic Research, 2020,29(04):728-737.

[5] Huang Jinfang. The Impact of Internet Development on Regional Economic Gap under the Background of Digital Economy: Based on the Perspective of Labor Factor Allocation [J].Business Economic Research, 2021(21):167-171.

[6] Pi Yabin. Study on the heterogeneous effect of regional integration on social welfare improvement [J].Modern Finance and Economics (Journal of Tianjin University of Finance and Economics), 2016,36(08):3-14.

[7] Xi Yue. Under the tide of digital procurement, Shang Yue is rising with the trend [J].China Logistics and Procurement, 2021(09):24-25.

[8] An Tongliang, Yang Chen. The Internet Reshapes China's Economic Geography: Micro Mechanisms and Macro Effects[J].Economic Research,2020,55(02):4-19.

[9] Yuan Chun, Xiao Tusheng, Geng Chunxiao, Sheng Yu. Digital Transformation and Enterprise Division of Labor: Specialization or Vertical Integration [J].China Industrial Economics, 2021, (09):137-155.

[10] Xu Lifang, Xu Zhiwei,WangPengfei. Financial Development and National Savings Rate: An Inverted U-Shaped Relationship[J].Economic Research,2017,52(02):111-124.

[11] Lu Hongyou, Zheng Fachuan, Jia Sha. Frontier Technological Progress, Technological Efficiency and Regional Economic Gap [J].Chinese, Resources and Environment, 2012, 22(05):120-125.

[12] Bian Yuanchao,Wu Lihua, Bai Junhong. The opening of high-speed rail, factor flow and regional economic gap [J].Finance and Trade Economics, 2018, 39(06):147-161.

[13] Zhao Tao, Zhang Zhi, Liang Shangkun. Digital Economy, Entrepreneurial Activity and High-quality Development: Empirical Evidence from Chinese Cities [J].Management World, 2020, 36(10):65-76.