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# Research on the Spatial Distribution Pattern and Influencing Factors of Digital Economy Development in China

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**ABSTRACT** The spatial heterogeneity of the influences of various driving factors on the digital economy restricts the further development of regional coordination. This paper constructs an index system for measuring the development level of the digital economy from the three dimensions of infrastructure construction, digital application and digital industry development. Using the entropy method to measure the development level of the digital economy in each region in 2018 and based on the theory of economic growth and new economic geography, a theoretical model of the influences of input factors, technological progress and institutional changes on China's digital economy is established. Combined with Exploratory Spatial Data Analysis (ESDA) and Geographically Weighted Regression (GWR) model analysis, the spatial distribution pattern of China's digital economy and its influencing factors are discussed. The results show that there is a large gap in the development level of the digital economy in the eight comprehensive economic regions, and the development level of the digital economy presents a significant spatial correlation in space. The driving patterns of input factors, technological progress and institutional changes to the spatial distribution of the digital economy show obvious spatial differentiation. This study provides important referential value for promoting the coordinated development of the regional digital economy.

**INDEX TERMS** Digital economy, ESDA, input factor, GWR, institutional change, technological progress.

## I. INTRODUCTION

With the advent of the digital age, numerous new models and new forms of business represented by data elements, digital technology and industrial transformation have arisen. The digital economy has emerged as the times have required and has become the new driving force for economic development. In 2016, the scale of China's digital economic added value was 22.6 trillion yuan, accounting for 30.3% of the country's GDP; it reached 35.8 trillion yuan in 2019 with year-on-year growth of 1.4%, accounting for 36.2% of the country's GDP [1]. This shows a trend of rapid growth of the digital economy. However, as many imbalanced problems appear in the development of the agricultural economy and industrial economy. The digital economy is a new form of social development. In the development process, due to different resource endowments, inputs, digital technology innovation and system support for the digital economy in different regions, the influence mechanism leads to different results and the outstanding problem of an uneven distribution of the digital economy. Therefore, regarding the regional digital economy development level, there is a large gap that causes the economic structural gap to continue to expand, which is bound to affect coordinated regional development. Therefore, how to accurately measure the development level of the digital economy in different regions of China, explore the spatial heterogeneity of the digital economy in different regions, and explore the sources of heterogeneity are particularly necessary for coordinated regional development.

Based on the above background, this paper will study the development of China's digital economy from a spatial perspective and explore its influencing factors. Based on the existing research results, this article expands this research in the following aspects. First, based on research on an

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indicator system for measuring the development level of the digital economy, the characteristics of the development level of China's digital economy and the basic establishment of an evaluation system, in principle, an indicator system with three dimensions (infrastructure construction, digital application, and digital industry development) is established in this study to measure the development level of the digital economy in each province. Second, based on the theory of economic growth and new economic geography and considering the characteristics of the penetration and sharing of the digital economy, we construct a spatial analysis framework for the impacts of input factors, technological progress, and institutional changes on China's digital economy. Third, we use the exploratory spatial data analysis (ESDA) method and combine it with the GWR model to compare the differences in the digital economy development of China's eight comprehensive economic zones and quantitatively analyze the influencing factors of their spatial differentiation in order to provide references and suggestions for the development of China's digital economy and to provide referential value for the coordinated development of the regional economy.

The remainder of this paper is arranged as follows: The second part is a literature review. The third part introduces the theoretical mechanism and hypothesis. The fourth part establishes the model and selects the variables. The fifth part describes the spatial distribution pattern of the development level of the digital economy. The sixth part details the empirical research. The seventh part provides the conclusions and suggestions.

## II. LITERATURE REVIEW

In academia, there are divergent opinions on the definition of the "digital economy". From a qualitative point of view, the digital economy is also called the "new economy". It is a special economic form that emphasizes the trading of goods and services in the digital form of new activities and new products [2], [3]. He (2005) postulated that the digital economy is a digital new economic form in which digital technology penetrates into the fields of manufacturing, management, and circulation and is based on knowledge and skills [4].

There are also some scholars and institutions that analyze the digital economy through the establishment of an indicator system from a quantitative perspective. Representative studies include Balcerzak and Pietrzak (2017), Zhang and Jiao (2017), Fan and Wu (2020), Wu and Zhang (2020). International organizations such as the European Union, the OECD, the U.S. Department of Commerce, the International Telecommunication Union, the China Academy of Information and Communications Technology, CCID Consulting, and the Shanghai Academy of Social Sciences have also measured the digital economy from different perspectives, and most of them have adopted mainstream comprehensive evaluation models such as the TOPSIS method, entropy method, principal component analysis method, expert scoring method, efficacy scoring method and other technical methods to measure the digital economy [5]–[8].

Regarding the research on the regional heterogeneity of China's digital economy development, the existing literature mainly focuses on comparative analyses among China's provinces and draws a more consistent conclusion that the digital economy development levels in the eastern, central, and western regions present a significant imbalance. The spatial distribution pattern is significantly different [9]–[11]. Many scholars are also concerned about the development of the regional digital economy and use the Theil index, geographic detector model, spatial autocorrelation and other methods to study the spatial differentiation pattern of the digital economy in Northeast China and the Yangtze River Economic Belt [12], [13].

Many factors affect the imbalanced development level of the digital economy. Modern economic growth theory states that the flexible allocation of the two basic elements of capital and labour and the rational use of scientific and technological inputs are the main driving forces for economic growth. Factors such as human capital, population quality, broadband communication, industrial structure, and other material inputs in various regions all play a role in the digital economy [14]. Technological progress is an endogenous factor and an important driving force for economic growth. Due to the limited number of traditional production factors, the dynamic mechanism of economic growth is gradually shifting to technological innovation. This is especially true in an era when existing digital technologies penetrate all walks of life. However, as economic theory has deepened, the school of new institutional economics has proposed that the ultimate decisive force of a country or region's economic growth lies in the system, and only through continuous institutional changes and innovations to adapt to economic development can society continue to progress [15]. The same is true for the development of the digital economy. The government supports science and technology and formulates various new economic policies so that the developing environment of the digital economy can be further optimized and the effective implementation of various digital technologies can be guaranteed to adapt to the pace of modern digital innovation [6], [9].

Existing documents have important insights for the development of the digital economy, but because China's digital economy is still relatively young, there are still many areas worthy of further study. First, there has never been a unified standard for measuring the digital economy. Different scholars and research institutions use different measurement perspectives and focuses due to differences in disciplinary backgrounds and research directions. Without a unified understanding, measurement methods are also easily controlled by other factors. Second, previous studies mostly focused on the traditional eastern, central, and western regions or provinces. The Development Research Center of the State Council of the People's Republic of China stated that the division of eastern, central, and western regions followed by China has become outdated and proposed dividing the mainland into eight specific comprehensive economic zones.[1] Finally, although the abovementioned literature has achieved some valuable research results on the regional differences in the development level of China's digital economy and its spatial distribution, most of the literature analyses the spatial distribution characteristics of the digital economy from multiple dimensions, and the spatial distribution pattern of the digital economy has been formed. The root causes are rarely discussed, and most previous studies use traditional measurement methods to explore the mechanism of the evolution of the spatial pattern of the digital economy. There are few documents that deeply explore the mechanism of the spatial heterogeneity of the development of the digital economy. However, everything and all individuals in space are related, and traditional methods have difficulty explaining the differences in the impacts of the indicators of different influencing factors on the digital economy in different regions, so they cannot reflect the true spatial distribution characteristics of the influencing factors [16]. The development level of the digital economy will change greatly with the spatial and geographic background conditions. The geographically weighted regression (GWR) model proposed by Brunsdon *et al.* (1998) can overcome the shortcomings of previous studies [17]. Therefore, this paper will proceed from these aspects to further study the spatial distribution pattern and influencing factors of China's digital economy.

## III. THEORETICAL MECHANISM AND HYPOTHESIS

There are many factors restricting economic growth. Classical economics takes the labour theory of value as the core and believes that population, land, material, and capital can promote economic development. Neoclassical economics pays more attention to the theory of utility value and equilibrium value and regards exogenous technological progress as the main driving force of economic development. The new growth theory believes that technological changes are internal forces and emphasizes knowledge spillover, human capital investment, etc. Then, the new system school proposed that the system is the core explanatory variable that affects economic development. Driven by existing digital technologies such as the Internet and big data, the digital economy has become China's new economic growth point with digital technology as the carrier. Relying on the penetrability, substitution and synergy of digital technology, the digital economy has quickly spread to all corners of social production and life. As a result, the growth of the digital economy is not only affected by natural resources, factor inputs, technology, systems and other factors but also has the characteristics of interconnection and sharing, and spatial factors have obvious influences [18]–[20].

### A. THE MECHANISM OF FACTOR INPUT ON REGIONAL DIGITAL ECONOMIC DEVELOPMENT DIFFERENCES

New economic geography is based on economic theory. It is believed that under imperfect competition, the transfer of production factors will spread from the centre to the periphery between regions in a "centre-periphery" model or gather from the periphery to the centre [21]. The leading role of new technologies such as artificial intelligence, drones, and 5G technology has accelerated the regional mobility of the two basic input elements of capital and labour, which has induced growth of physical capital and gradually accumulated human capital from the periphery to the centre. The effect of knowledge spillover is also more obvious, as it has widened the regional differences in the digital economy.

Hypothesis 1: Factor inputs in different regions have different influences on the development of the digital economy, and there is regional heterogeneity.

### B. THE MECHANISM OF TECHNOLOGICAL PROGRESS ON REGIONAL DIGITAL ECONOMIC DEVELOPMENT DIFFERENCES

In the era of the digital economy, owing to the development of digital technology, production efficiency has been greatly improved, which greatly promotes the development of the economy. The ability of the digital economy to radiate outward is improved accordingly, and the leading role of the digital economy in neighbouring areas is enhanced, which is conducive to the overall development of the digital economy. However, because regional activities subject to digital technology are limited, generally, the economy in a relatively developed area benefits from the early introduction of digital technology, more digital individuals, more digital enterprises, a broader digital government application scenario, and a strong digital development ability. However, in economically poor regions, the acceptance of new technology is low. Therefore, technological development is not very balanced, and the heterogeneity of the digital economy is developing.

Hypothesis 2: Technological progress is a favourable tool to improve the development level of the digital economy in China. The development level of the digital economy will be different due to the different degrees of acceptance of new technology in different regions.

### C. THE MECHANISM OF INSTITUTIONAL CHANGES ON REGIONAL DIGITAL ECONOMIC DEVELOPMENT DIFFERENCES

In order to adapt to the development of emerging industries such as electronics, information and new energy and to promote industrial transformation and upgrading, various

[1] In June 2005, the Development Research Center of the State Council of China divided the inland into eight comprehensive economic zones, namely, the Northeast Comprehensive Economic Zone (Liaoning, Jilin, and Heilongjiang), the Northern Coastal Comprehensive Economic Zone (Beijing, Tianjin, Hebei, and Shandong), the Eastern Coastal Comprehensive Economic Zone (Shanghai, Jiangsu, and Zhejiang), the Southern Coastal Comprehensive Economic Zone (Fujian, Guangdong, and Hainan), the Comprehensive Economic Zone in the Middle Reaches of the Yellow River (Shaanxi, Shanxi, Henan, and Inner Mongolia), the Comprehensive Economic Zone in the Middle Reaches of the Yangtze River (Hubei, Hunan, Jiangxi, and Anhui), the Great Southwest Comprehensive Economic Zone (Yunnan, Guizhou, Sichuan, Chongqing, and Guangxi), and the Great Northwest Comprehensive Economic Zone (Gansu, Qinghai, Ningxia, Tibet, and Xinjiang).

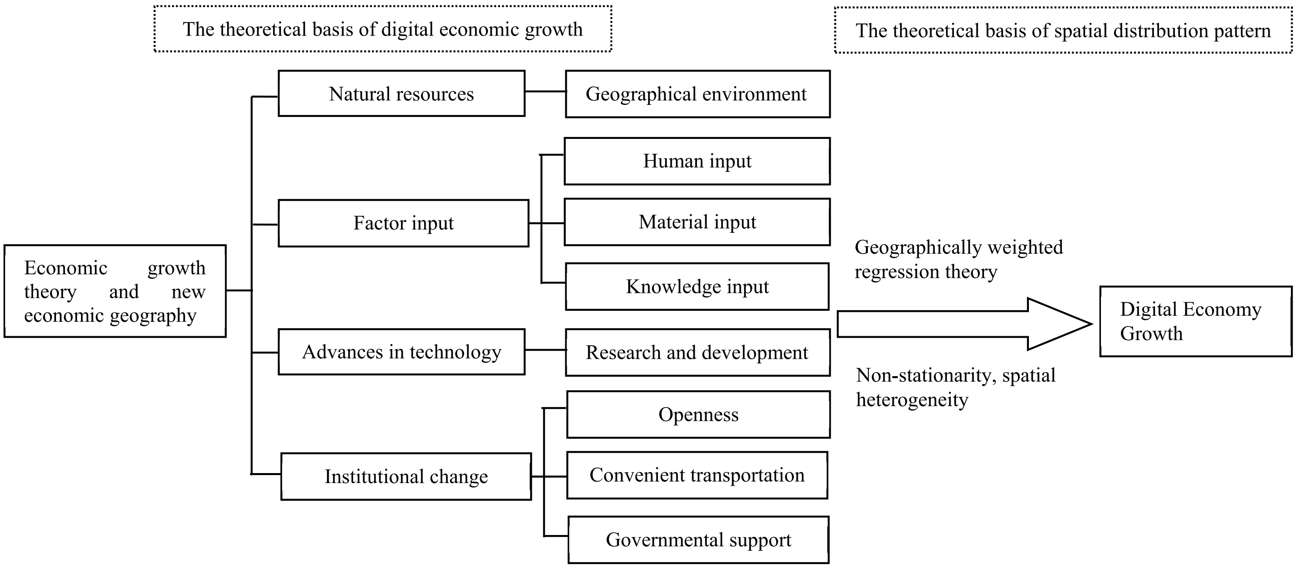


**FIGURE 1.** **Research framework.**

regions have introduced various new digital economy policies and implemented a series of institutional reforms with the support of digital technology. North stated in the theory of institutional change that institutions are the final deciding force of the economic growth of a region or a country. Institutional changes are the driving force of regional economic growth. The ways, paths, scales, speeds, effects and impacts of institutional changes in different regions have produced differences in regional economic growth. For example, the degree of openness and transportation convenience in China's coastal areas is far greater than that in the central and western regions, and the support of various local governments in science and technology will affect the development of the digital economy.

Hypothesis 3: Institutional changes in various regions are an important guarantee for adapting to digital development and promoting the development of China's digital economy.

The research design of this article is to build a theoretical framework based on the above mechanisms and study the spatial distribution pattern of the development of the digital economy and the mechanisms of influencing factors, as shown in Figure 1.

## IV. MODEL SETTING AND DATA SOURCE

### A. MODEL SETTING

According to the above theoretical analysis, in order to explore the root causes of the development level of the digital economy in each region, this paper uses the Cobb-Douglas production function, and the explanatory variable is the development level of the digital economy (Y). The explanatory variables are the factor input, technological progress and institutional change that affect the development of the digital economy. Among these explanatory variables, the human input of the factor input is represented by the number of college graduates (HC), the material input is represented by the per capita investment in fixed assets (K), and the knowledge input is represented by the proportion of R&D expenditures with respect to GDP (RD). Technological progress is represented by the number of patents per 10,000 people (TP). In the process of institutional change, the proportion of total trade imports and exports with respect to the GDP of each region (XM) is used to measure the degree of openness to the outside world, transportation convenience is represented by the highway mileage of each region (TC), and government support is measured by the proportion of general public budget expenditures with respect to the GDP of each region (GS). The model is set as follows:

$$Y = AK^{\alpha_1}(HC)^{\alpha_2}(RD)^{\alpha_3}(TP)^{\alpha_4}e^{\alpha_5 XM+\alpha_6 TC+\alpha_7 GS} \quad (1)$$

where $\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 = 1$. Taking the logarithm of both sides of equation (1) yields:

$$LnY = LnA + \alpha_1 LnK + \alpha_2 Ln(HC) + \alpha_3 Ln(RD) + \alpha_4 Ln(TP) + \alpha_5 XM + \alpha_6 \mathrm{TC} + \alpha_7 GS \quad (2)$$

However, the traditional econometric model usually assumes that the independent variables and dependent variables are stable; that is, the variables will not change with the spatial movement of the sample, or the parameters are considered to be spatially stationary. With the rapid development of digital technologies such as cloud computing and artificial intelligence, the digital economy has crossed the boundaries of traditional geographical distance and spatial distance, and its spatial fluidity is more obvious. As a result, the parameters of the influencing factors will also change with the spatial movement of samples. Therefore, the measurement results using the traditional model are obviously inconsistent with the fact that the parameter space is not stationary. In the following part of this paper, the variable coefficient GWR

**TABLE 1.** Descriptive statistics of each variable.

| variable | Average | Standard deviation | Minimum | Maximum | VIF |
|---|---|---|---|---|---|
| Human input ($10^4$ people) | 12.8760 | 7.0949 | 0.8300 | 26.2000 | 3.85 |
| Material input ($10^4$ RMB/person) | 0.0781 | 0.0263 | 0.0225 | 0.1248 | 1.50 |
| Knowledge input (%) | 0.2996 | 0.4721 | 0.0745 | 2.5019 | 1.59 |
| Technical progress (pieces) | 15.2747 | 15.4115 | 3.5246 | 57.3333 | 6.80 |
| Openness (%) | 24.3685 | 24.4487 | 1.7540 | 94.4470 | 8.20 |
| Convenience of transportation ($10^5$ km) | 15.8292 | 8.3600 | 1.3106 | 33.1592 | 3.23 |
| Government support (%) | 26.2965 | 10.6300 | 12.4915 | 59.9502 | 3.19 |

model is introduced to solve the nonstationary problem of the parameter space of the impact factors of the digital economy. The specific form of the model is as follows:

$$\begin{aligned} LnY_i = {} & \alpha_0 (u_i, v_i) + \alpha_1 (u_i, v_i) Ln(K_{i1}) \\ & + \alpha_2 (u_i, v_i) Ln(HC_{i2}) + \alpha_3 (u_i, v_i) Ln(RD_{i3}) \\ & + \alpha_4 (u_i, v_i) Ln(TP_{i4}) + \alpha_5 (u_i, v_i) XM_{i5} \\ & + \alpha_6(u_i, v_i)TC_{i6} + \alpha_7(u_i, v_i)GS_{i7} + \varepsilon_i \end{aligned} \tag{3}$$

In the above formulas, $(u_i, v_i)$ represents the geographic coordinates of region $i$, $x_{ik} (k = 1, \ldots, 7)$ represents the interpreted value of the independent variable in locale $i$, $\alpha_k(u_i, v_i)$ represents the regression parameter at the centroid $(u_i, v_i)$ of region $i$ in the study area, and $\varepsilon_i$ represents the random error term.

### B. DATA SOURCE

The social and economic data for each variable mainly come from the China Statistical Yearbook. In view of the availability of the data on various indicators of the digital economy, the sample is set as the cross-sectional data of 30 provinces (municipalities and autonomous regions) excluding Tibet, Hong Kong, Macao and Taiwan in 2018. The descriptive statistical results of each variable are shown in Table 1. The VIF of the explanatory variable shows that the maximum VIF is 8.20, which is less than 10, indicating that there is no collinearity among the explanatory variables.

## V. THE SPATIAL DISTRIBUTION PATTERN OF THE DEVELOPMENT LEVEL OF THE DIGITAL ECONOMY

### A. MEASUREMENT OF THE DEVELOPMENT LEVEL OF THE DIGITAL ECONOMY

Although there are some research results on the measurement of the development level of the digital economy, there are still differences in the connotation and scope of the digital economy, and a unified index system for quantifying the development level of the digital economy has not been established. The research conclusions have certain controversies and limitations. We explore the reasons for the spatial heterogeneity of the development level of the digital economy. The development level of the digital economy is the core explanatory variable. Therefore, it is very important to construct a proxy variable that can reasonably measure the development level of the digital economy. The development level of the digital economy is a multi-dimensional comprehensive concept with rich connotations. However, there is no unified understanding of the application of comprehensive indicators in previous studies. This paper holds that the construction of digital economic infrastructure is the cornerstone of the integration of digital elements and traditional elements, digital application is an important embodiment of the penetration of digital technology in various economic subjects, and the development of the digital industry is the main way to optimize the industrial structure and intellectualize the development mode of a country. Therefore, after summarizing the indicator system for measuring the development level of the digital economy, in accordance with the characteristics of China's digital economy development level and the basic principles established by the evaluation system, a total of three indicators are established: infrastructure construction, digital application, and digital industry development. The evaluation index system composed of 3 first-level indicators, 7 second-level indicators, and 19 three-level indicators is listed in Table 2.

Entropy value method is originally developed from the concept of information entropy. Its main idea is to establish the weight by determining the degree of dispersion of indicators, and then form a comprehensive evaluation system method. Such methods are usually based on macro data, which is more scientific and objective than subjective judgment. In this paper, the development level of digital economy is evaluated from three aspects of infrastructure construction, digital application and digital industry development. According to their respective influence degrees, entropy method is used to determine the weight, and the final comprehensive evaluation results are obtained according to the calculation of each index value. Through the results to judge the extent of regional digital economy development.

Firstly, the original data are normalized:

$$x'_{ij} = 0.1 + 0.9 * \frac{x_{ij} - min(x_{ij})}{max\left(x_{ij}\right) - min(x_{ij})} \tag{4}$$

**TABLE 2.** Evaluation system of the digital economic development level.

| Integrated indicators | First-level indicators | Secondary indicators | Three-level indicators | Unit | Indicator attributes |
|---|---|---|---|---|---|
| Digital economy development level | Digital infrastructure (A1) | Hardware foundation (B1) | Internet broadband access ports (C1) | $10^4$ | + |
| | | | Mobile phone base stations (C2) | $10^4$ | + |
| | | | Optical cable line length (C3) | km | + |
| | | Software foundation (B2) | Number of websites (C4) | $10^4$ | + |
| | | | Number of domain names (C5) | $10^4$ | + |
| | | | Number of Internet pages (C6) | $10^4$ | + |
| | | | Number of IPv4 addresses (C7) | $10^4$ | + |
| | Digital application (A2) | Digital individuals (B3) | Mobile Internet access traffic (C8) | $10^4$ G | + |
| | | | Telephone penetration rate (C9) | pieces/$10^2$ people | + |
| | | | Internet broadband access users (C10) | $10^4$ households | + |
| | | Digital enterprises (B4) | Proportion of companies with e-commerce transaction activities (C11) | % | + |
| | | | Number of websites owned by every 100 companies (C12) | pieces | + |
| | | Digital government (B5) | Government microblogging (C13) | pieces | + |
| | | | Government website (C14) | pieces | + |
| | | | Government headlines (C15) | pieces | + |
| | Digital industry development (A3) | Industry reserve (B6) | Number of R&D personnel (C16) | $10^4$ people | + |
| | | | Number of employees in information transmission, software and information services and manufacturing of computers, communications and other electronic equipment (C17) | $10^4$ people | + |
| | | Industry benefit (B7) | Software business revenue as a percentage of GDP (C18) | % | + |
| | | | Proportion of high-tech products exports with respect to GDP (C19) | % | + |

Data source: Indicators C1-C12 and C17-C19 are from the China Statistical Yearbook, indicators C13-C15 are from the China Internet Development Statistical Report, and indicator C16 is from the China Science and Technology Statistical Yearbook.

where $x_{ij}$ is the index value of a certain index in the jth area and $max(x_{ij})$ *and* $\min(x_{ij})$ respectively represent the maximum value and the minimum value of a certain index value in all areas.

Then, the specific gravity, entropy value and difference coefficient of each index are calculated to obtain the weights and comprehensive scores. The results are shown in Table 3.

### B. SPATIAL DISTRIBUTION CHARACTERISTICS

With the in-depth integration of digital technology and various economic entities, the digital economy has achieved initial successes and has become a new growth point for the Chinese economy. However, the spatial distribution of the digital economy is uneven, and there is still a large gap between China's digital economy and that of some developed countries. Table 3 shows that the overall level of China's digital economy development is low, and regional differences are obvious. The development levels of the Northern Coastal Economic Zone, the Eastern Coastal Economic Zone, and the Southern Coastal Economic Zone are higher than the overall national level. In contrast, those of the Northeast Economic Zone, the Middle Yangtze River Economic Zone, the Southwest Economic Zone and the Northwest Economic Zone are far below the overall level of the country. Among the different regions, the Northwest Economic Zone has the lowest development level at 0.0179.

In order to deeply explore the differences in the levels of digital economic development in various regions, the scores of the digital economic development level calculated above are used to draw a quantile map of China's 2018 digital economic index. The digital economy level of each region is classified from low to high in 5 steps by the natural fracture point method. Table 4 shows that the provinces with close gradients are basically adjacent; that is, China's digital economy has a relatively obvious spatial agglomeration effect in the provincial space. The digital economy development levels in the coastal areas are much higher than those in the inland areas, while the digital economy development levels in the middle reaches of the Yellow River and the middle reaches of the Yangtze River are higher than those in the southwest, northwest and northeast regions. The spatial distribution of the development of China's digital economy presents declining trends from the coastal areas to the inland areas and from the centre to the periphery.

### C. SPATIAL CORRELATION FEATURE

Understanding the spatial agglomeration and distribution of China's digital economy is the starting point for analyzing the imbalanced spatial distribution of the digital economy. The global autocorrelation Moran's I index is 0.2310, and the standardized test Z(I) value is 2.3463. This value is significant at the 0.05 level, which shows that the development level of China's digital economy presents a spatially positively

**TABLE 3.** Comprehensive scores of the digital economy.

| Province | Score | Rank | Province | Score | Rank |
|---|---|---|---|---|---|
| Heilongjiang | 0.0203 | 26 | Hubei | 0.0301 | 14 |
| Jilin | 0.0204 | 25 | Hunan | 0.0284 | 15 |
| Liaoning | 0.0277 | 16 | Jiangxi | 0.0253 | 17 |
| Northeast Economic Zone | 0.0228 | | Anhui | 0.0301 | 11 |
| Beijing | 0.0697 | 2 | Middle Yangtze River Economic Zone | 0.0285 | |
| Tianjin | 0.0251 | 19 | Yunnan | 0.0227 | 21 |
| Hebei | 0.0301 | 12 | Guizhou | 0.0220 | 22 |
| Shandong | 0.0464 | 6 | Sichuan | 0.0435 | 8 |
| Northern Coastal Economic Zone | 0.0428 | | Chongqing | 0.0301 | 13 |
| Shanghai | 0.0440 | 7 | Guangxi | 0.0253 | 18 |
| Jiangsu | 0.0567 | 4 | Southwest Economic Zone | 0.0287 | |
| Zhejiang | 0.0507 | 5 | Gansu | 0.0215 | 24 |
| Eastern Coastal Economic Zone | 0.0505 | | Qinghai | 0.0153 | 30 |
| Fujian | 0.0610 | 3 | Ningxia | 0.0165 | 29 |
| Guangdong | 0.0802 | 1 | Xinjiang | 0.0181 | 28 |
| Hainan | 0.0186 | 27 | Northwest Economic Zone | 0.0179 | |
| Southern Coastal Economic Zone | 0.0533 | | Nationwide | 0.0333 | |
| Shaanxi | 0.0323 | 10 | | | |
| Shanxi | 0.0239 | 20 | | | |
| Henan | 0.0424 | 9 | | | |
| Inner Mongolia | 0.0215 | 23 | | | |
| Middle Yellow River Economic Zone | 0.0300 | | | | |

**TABLE 4.** Spatial distribution of China's digital economy development level.

| Comprehensive economic zone | Lowest level | Low level | Medium level | High level | Highest level |
|---|---|---|---|---|---|
| Northeast Economic Zone | Heilongjiang and Jilin | | Liaoning | | |
| Northern Coastal Economic Zone | | Tianjin | Hebei | Shandong | Beijing |
| Eastern Coastal Economic Zone | | | | Jiangsu, Zhejiang, and Shanghai | |
| Southern Coastal Economic Zone | Hainan | | | | Guangdong and Fujian |
| Middle Yellow River Economic Zone | | Shanxi and Inner Mongolia | Shaanxi | Henan | |
| Middle Yangtze River Economic Zone | | Jiangxi | Hubei, Hunan, and Anhui | | |
| Southwest Economic Zone | | Guangxi, Yunnan, and Guizhou | Chongqing | Sichuan | |
| Northwest Economic Zone | Xinjiang, Ningxia, and Qinghai | Gansu | | | |

correlated agglomeration feature in various regions. This is the prerequisite for the practicability of the spatial measurement model and lays the foundation for the validity of the GWR model.

Next, in order to further explore the spatial distribution pattern of the development level of the digital economy in each region, Moran's I scatter plot is selected for the local spatial autocorrelation test. The four quadrants of the Moran's I scatter chart represent the four local spatial correlation categories of high-high, low-high, low-low and high-low development levels of China's digital economy. As shown in Figure 2, the development level of the digital economy in most provinces is in the first and third quadrants, while the development level of the digital economy is in the second and fourth quadrants in only a few provinces. This shows that the development level of the digital economy of these 30 provinces (cities and autonomous regions) in China has a positive spatial correlation, which further confirms that China's digital economy is characterized by spatial agglomeration.

## VI. EMPIRICAL ANALYSIS ON THE INFLUENCING FACTORS OF THE DEVELOPMENT LEVEL OF THE DIGITAL ECONOMY

Through the above research, we find that the development level of China's digital economy is characterized by regional

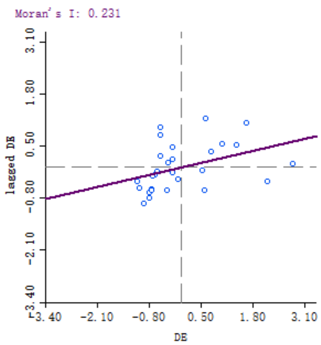


**FIGURE 2.** Moran's I scatter diagram of the digital economy development level of China's provinces.

heterogeneity and spatial aggregation among the eight comprehensive economic zones. In order to explore the driving factors of this imbalance, the GWR model is used to thoroughly analyze the mechanism by which various factors actively influence the development level of China's digital economy.

### A. MODEL PARAMETER ESTIMATION RESULTS

Using the comprehensive score of the development level of the digital economy as the dependent variable and factor input and using technological progress and institutional change as the independent variables, ArcGIS10.5 software is used to estimate the variables of the GWR model constructed above, and the AIC is used to select the optimal bandwidth of the model. That is, when the minimum AIC occurs, the bandwidth is optimal, and then the GWR model is the most effective. The model parameter results are shown in Table 5. The adjusted $R^2$ is 0.7824, indicating that the fitting effect is good.

**TABLE 5.** GWR model parameters.

| Parameter | GWR |
|---|---|
| Bandwidth | 35,493,223.0539 |
| Residual Squares | 13.0409 |
| Effective Number | 8.0168 |
| Sigma | 0.7702 |
| $AIC_C$ | 87.1797 |
| $R^2$ | 0.8350 |
| Adjusted $R^2$ | 0.7824 |

### B. ANALYSIS OF THE SPATIAL PATTERN OF ACTIVE INFLUENCING FACTORS

#### 1) IMPACT OF FACTOR INPUT

Table 6 shows that the regression coefficients of human input in the eight comprehensive economic zones are all positive, and the degree of influence is high in the Northwest and Southwest Economic Zones along the middle reaches of the Yangtze River and the middle reaches of the Yellow River and decreases to the northeast. Human investment is an important factor in the growth of the digital economy. In economically developed areas, labour is easier to acquire. When the matching of various positions is saturated, increasing human investment will not lead to better development of the digital economy, which is more serious than the brain drain. Increasing the marginal productivity of talent investment can significantly improve the regions in which talent is scarce, especially in the western regions. Increasing human capital investment can effectively improve the development level of the digital economy.

Material input is the factor with the largest degree of influence among all influencing factors. It has a positive relationship with the overall development of the digital economy, and the regression coefficient is [1.242708∼1.256753]. Regarding the spatial pattern of the coefficient values, high values tend to concentrate in the southern and eastern coastal areas; the maximum values are located in Shanghai, Zhejiang, Fujian, Guangdong, Hainan and other places, while the lowest values are located in Xinjiang. This means that compared with the areas with poor talent input, material input is more inclined to the coastal and inland areas with good geographical conditions. Due to the unique profit-driven nature of capital, entrepreneurs are more inclined to invest capital in areas with high economic returns, and this eventually forms a vicious cycle of poverty, which further widens the difference between the development of the digital economy in Northwest China and coastal and Central China.

Knowledge input can obviously promote the development of the digital economy in each region, and its degree of influence is between those of material input and human input. Table 8 shows that the regression coefficients in Northeast China are of high value to Central, Southwest, and Northeast China, which have poor environmental bearing capacities. The traditional industry technical content is low, and industrial structure adjustment and traditional industry transfer are inevitable choices. Therefore, increased knowledge investment in Northeast China can effectively promote the development of the digital economy.

#### 2) IMPACT OF TECHNOLOGICAL PROGRESS

Owing to the rapid development of modern science and technology, the replacement of traditional heavy labour by technologies such as the Internet of Things and artificial intelligence has effectively improved productivity under the same amounts of existing capital and labour input. Table 9 shows that the impact of technological differences on the digital economy varies in different regions, and the regression coefficient of technological progress decreases in the middle and south directions with the northern region having a high value. Technology can optimize the economic structure. Science and technology play a considerable role in digital economic development. The technological development in the north is relatively backward. The promotion of science and technology can greatly improve the labour productivity of a region's entire industry. This can promote the digital economy to raise the level of economic development. The level of science and technology in the southern region is higher, so other ways

**TABLE 6.** Spatial distribution of the regression coefficients of human input.

| Coefficient range | [0.065359~ 0.065375] | [0.065376~ 0.065401] | [0.065402~ 0.065421] | [0.065422~ 0.065447] | [0.065448~ 0.065480] |
|---|---|---|---|---|---|
| Northeast Economic Zone | Heilongjiang, Jilin, and Liaoning | | | | |
| North Coastal Economic Zone | | Beijing, Tianjin, Hebei, and Shandong | | | |
| Eastern Coastal Economic Zone | | Jiangsu, Zhejiang, and Shanghai | | | |
| Southern Coastal Economic Zone | | Fujian | Guangdong | Hainan | |
| Middle Yellow River Economic Zone | | Inner Mongolia | Shanxi, Shaanxi, and Henan | | |
| Middle Yangtze River Economic Zone | | Anhui | Hubei, Hunan, and Jiangxi | | |
| Southwest Economic Zone | | | | Guizhou, Guangxi, Sichuan, and Chongqing | Yunnan |
| Northwest Economic Zone | | | | Gansu and Ningxia | Xinjiang and Qinghai |

**TABLE 7.** Spatial distribution of the regression coefficients of material input.

| Coefficient range | 1.242708 | [1.242709~ 1.250540] | [1.250541~ 1.253220] | [1.253221~ 1.255018] | [1.255019~ 1.256753] |
|---|---|---|---|---|---|
| Northeast Economic Zone | | | Heilongjiang, Jilin, and Liaoning | | |
| North Coastal Economic Zone | | | Beijing, Tianjin, and Hebei | Shandong | |
| Eastern Coastal Economic Zone | | | | Jiangsu | Zhejiang, Shanghai |
| Southern Coastal Economic Zone | | | | | Fujian, Guangdong, and Hainan |
| Middle Yellow River Economic Zone | | Inner Mongolia | Shanxi, Shaanxi, and Henan | | |
| Middle Yangtze River Economic Zone | | | | Anhui, Hubei, and Hunan | Jiangxi |
| Southwest Economic Zone | | Sichuan | Guizhou, Yunnan, and Chongqing | Guangxi | |
| Northwest Economic Zone | Xinjiang | Qinghai, Gansu, and Ningxia | | | |

to promote the development of the digital economy can be considered.

#### 3) IMPACT OF INSTITUTIONAL CHANGE

Compared with factor input and technological progress, institutional change has less impact on the development level of China's digital economy. As shown in Table 10, the regression coefficients of openness to the outside world have high values in the southern coastal regions, the Southwest Economic Zone and other southern regions and decreases from the central region to the north. In the northwest and northeast regions, openness to the outside world has the least impact on the digital economy. This shows that increasing openness in the coastal and central regions can significantly promote

**TABLE 8. Spatial distribution of the regression coefficients of knowledge input.**

| Coefficient range | [0.183227~ 0.183700] | [0.183701~ 0.184344] | [0.184345~ 0.184771] | [0.184772~ 0.185218] | [0.185219~ 0.186126] |
| --- | --- | --- | --- | --- | --- |
| Northeast Economic Zone | | | | | Heilongjiang, Jilin, and Liaoning |
| North Coastal Economic Zone | | | | Beijing, Tianjin, Hebei, and Shandong | |
| Eastern Coastal Economic Zone | | | Jiangsu, Zhejiang, and Shanghai | | |
| Southern Coastal Economic Zone | Guangdong and Hainan | Fujian | | | |
| Middle Yellow River Economic Zone | | | Shaanxi and Henan | Shanxi | Inner Mongolia |
| Middle Yangtze River Economic Zone | | Hubei, Hunan, and Jiangxi | Anhui | | |
| Southwest Economic Zone | Yunnan and Guangxi | Sichuan and Chongqing | Guizhou | | |
| Northwest Economic Zone | | | Qinghai, Gansu and Ningxia | Xinjiang | |

**TABLE 9. Spatial distribution of the regression coefficients of technological progress.**

| Coefficient range | [0.066796~ 0.066808] | [0.066809~ 0.066824] | [0.066825~ 0.066834] | [0.066835~ 0.066847] | [0.066848~ 0.066868] |
| --- | --- | --- | --- | --- | --- |
| Northeast Economic Zone | | | | Jilin, Liaoning | Heilongjiang |
| North Coastal Economic Zone | | | Shandong | Beijing, Tianjin, and Hebei | |
| Eastern Coastal Economic Zone | | Jiangsu, Zhejiang, and Shanghai | | | |
| Southern Coastal Economic Zone | Guangdong and Hainan | Fujian | | | |
| Middle Yellow River Economic Zone | | | Shaanxi and Henan | Shanxi | Inner Mongolia |
| Middle Yangtze River Economic Zone | | Hubei, Hunan, Jiangxi, and Anhui | | | |
| Southwest Economic Zone | Guangxi | Yunnan, Guizhou, and Chongqing | Sichuan | | |
| Northwest Economic Zone | | | | Qinghai, Gansu, and Ningxia | Xinjiang |

the development of the digital economy. The coastal areas of Guangdong and Hainan and border provinces such as Yunnan and Guangxi have relatively high degrees of openness, which have greater impacts on the digital economy. However, increasing the degree of openness in most areas of Northwest and Northeast China cannot promote the development of the digital economy.

Convenience of transportation has the most influential positive role in institutional change for the development of the digital economy. As Table 11 shows, the regression coefficients of transportation convenience decrease from Heilongjiang and Jilin in the northeast as the high-value centre to Yunnan in the southwest. Low-value centres are observed in the Southwestern and Southern Coastal Economic Zones. The results show that improving transportation convenience in Northeast China can significantly improve the development level of the digital economy, while the central and coastal regions have more convenient transportation, and

**TABLE 10. Spatial distribution of the regression coefficients of openness.**

| Coefficient range | [0.011552~ 0.011570] | [0.011571~ 0.011584] | [0.011585~ 0.011596] | [0.011597~ 0.011611] | [0.011612~ 0.011631] |
|---|---|---|---|---|---|
| Northeast Economic Zone | Jilin, Liaoning, and Heilongjiang | | | | |
| North Coastal Economic Zone | | Shandong, Beijing, Tianjin, and Hebei | | | |
| Eastern Coastal Economic Zone | | | Jiangsu and Shanghai | Zhejiang | |
| Southern Coastal Economic Zone | | | | Fujian | Guangdong and Hainan |
| Middle Yellow River Economic Zone | Inner Mongolia | Shanxi | Shaanxi and Henan | | |
| Middle Yangtze River Economic Zone | | | Anhui | Hubei, Hunan, and Jiangxi | |
| Southwest Economic Zone | | | | Sichuan, Guizhou, and Chongqing | Yunnan and Guangxi |
| Northwest Economic Zone | Xinjiang | Gansu and Ningxia | Qinghai | | |

**TABLE 11. Spatial distribution of the regression coefficients of transportation convenience.**

| Coefficient range | [0.043562~ 0.043585] | [0.043586~ 0.043607] | [0.043608~ 0.043629] | [0.043630~ 0.043655] | [0.043656~ 0.043683] |
|---|---|---|---|---|---|
| Northeast Economic Zone | | | | Liaoning | Jilin and Heilongjiang |
| North Coastal Economic Zone | | | | Shandong, Beijing, Tianjin, and Hebei | |
| Eastern Coastal Economic Zone | | | Jiangsu, Shanghai, and Zhejiang | | |
| Southern Coastal Economic Zone | Guangdong and Hainan | Fujian | | | |
| Middle Yellow River Economic Zone | | | Shaanxi, Henan, and Shanxi | Inner Mongolia | |
| Middle Yangtze River Economic Zone | | Hubei, Hunan, and Jiangxi | Anhui | | |
| Southwest Economic Zone | Guizhou, Yunnan, and Guangxi | Sichuan and Chongqing | | | |
| Northwest Economic Zone | | Qinghai | Xinjiang, Gansu, and Ningxia | | |

enhancing the transportation infrastructure construction has less of a promotional effect on the development of the digital economy.

Among all the driving factors, the degree of government support has the lowest promotional effect on the development of the digital economy. As shown in Table 12, the degree of government support has the highest influence on the digital economy in Northwest China. The effect decreases to Jiangsu, Zhejiang, Fujian and other coastal areas and forms a low-value centre in Heilongjiang, Jilin and the eastern coastal areas. These results show that increasing government support in the northwest and western regions can significantly promote the improvement of the development level of the digital economy, and Xinjiang, Qinghai and other ethnic minority regions have higher government support. Although the development of the western region is backward, the development

**TABLE 12.** Spatial distribution of the regression coefficients of government support.

| Coefficient range | [0.000012~ 0.000022] | [0.000023~ 0.000030] | [0.000031~ 0.000053] | [0.000054~ 0.000082] | [0.000083~ 0.0000131] |
|---|---|---|---|---|---|
| Northeast Economic Zone | Heilongjiang and Jilin | Liaoning | | | |
| North Coastal Economic Zone | | Shandong | Beijing, Tianjin, and Hebei | | |
| Eastern Coastal Economic Zone | Jiangsu, Shanghai, and Zhejiang | | | | |
| Southern Coastal Economic Zone | Fujian | Guangdong | Hainan | | |
| Middle Yellow River Economic Zone | | | Inner Mongolia, Shanxi, and Henan | Shaanxi | |
| Middle Yangtze River Economic Zone | | Anhui and Jiangxi | Hubei and Hunan | | |
| Southwest Economic Zone | | | Guangxi | Yunnan, Sichuan, Guizhou, and Chongqing | |
| Northwest Economic Zone | | | | Gansu and Ningxia | Xinjiang and Qinghai |

of the western region is crucial for the strategy of coordinated regional development. In recent years, China has paid increasing more attention to the western region, which has a greater impact on the digital economy.

## VII. RESEARCH CONCLUSIONS AND POLICY RECOMMENDATIONS

Based on the theory of economic growth and new economic geography, this paper finds that factor inputs, technological progress and institutional change have impacts on the development of the digital economy through theoretical derivation. Then, using the Cobb-Douglas production function as the starting point, the spatial distribution pattern and influencing factors of China's digital economy are visualized by the ESDA and GWR methods. The results show the following: 1. The spatial characteristics of China's digital economy are represented by a large gap in the development level of the digital economy among regions. The digital economy is mainly concentrated in coastal areas and the middle reaches of the Yangtze and Yellow Rivers. The development level of the digital economy in different regions is not randomly distributed but presents a significant spatial positively correlated agglomeration distribution. 2. The influencing factors of factor inputs have different influence modes on the development of the digital economy, showing obvious spatial differentiation. The influence of factor inputs on the spatial distribution of the digital economy is positively correlated in all provinces. The most significant areas of human input influence are mainly concentrated in Southwest and Northwest China. The most significant area of material input influence is mainly concentrated in the southeastern coastal area of China. The most significant areas of knowledge input influence are the three provinces of Northeast China and Inner Mongolia. 3. The influence of technological progress on the spatial distribution of the digital economy is positively correlated in all provinces, and the degree of influence decreases from north to south. 4. Among the influencing factors of institutional change, openness to the outside world and the convenience of transportation play more significant roles in promoting the digital economy. The most significant impact of openness is mainly concentrated in the southern part of China, with high impacts in the south and low impacts in the north. The most significant impact of transportation convenience is mainly concentrated in Heilongjiang and Jilin. The influence of the degree of government support on the digital economy is small, and the areas with the most significant impact are mainly concentrated in Xinjiang and Qinghai.

Based on the above results, in order to effectively solve the problem of the imbalanced development of China's digital economy and promote coordinated regional development, the following suggestions are proposed: 1. Deepen regional cooperation and strengthen regional contacts to further enhance the digital capabilities in coastal areas and the middle reaches of the Yangtze and Yellow Rivers. A digital economy coastal cooperation pilot zone should be established to give full play to the digital capability of the hinterland region, thus driving the development of the digital economy in Northwest China. 2. From the perspective of factor inputs, first, the level of human capital should be improved. The level of human capital plays a tremendous role in China's digital economy; in particular, improving the human capital level in the western region will significantly affect the development level of the digital economy. In accordance with the comprehensive strategic deployment of talent and science and technology, training local senior technical personnel will reduce the costs of human resources. Second, to strengthen the material input of the southeast, the southeast population is dense and the per capita share of resources is small; therefore, increasing the material input can effectively stimulate the development of the digital economy. Third, the knowledge input in Northeast China should be increased, industrial transformation and upgrading should be accelerated, and the overall competitiveness of technology-intensive industries in Northeast China should be increased. 3. From the perspective of technological progress, investments in science and technology in the northern region should be increased, the protection of patent and intellectual property rights should be strengthened, and a green and efficient knowledge economy environment should be established. 4. From the perspective of institutional change, first, to further increase the openness of the southern coastal areas and areas adjacent to other countries, regional advantages should be utilized, and more foreign resources should be introduced. Second, investments in regional transportation infrastructure construction should be increased, especially to strengthen the link between the middle reaches of the Yangtze River and the Yellow River and the northeast. Third, full play should be given to the guiding role of the government, and various supportive policies should be introduced in accordance with local conditions to promote the development of the digital economy in the northwest.

It should be admitted that the index system established in this paper cannot be dynamically studied in the form of time series due to the limitation of data, but the results obtained are consistent with the current development of China and have certain reference value. It is believed that with the development of time and the improvement of technical level, a more perfect index system can be established to dynamically track the development of China's digital economy, which is also one of the directions of our future efforts.

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