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Analysis of Regional Differences in China's Digital Economy Development and Dynamic Evolution

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Abstract: *This paper mainly evaluates three aspects, namely digital infrastructure, R&D and digital industry development, uses entropy weight-TOPSIS method to measure the level of China's digital economy development and adopts the spatial Markov method, Dagum's Gini coefficient and Kernel Density Estimation to analyse the regional differences and dynamic evolution. The study found that:Firstly, the level of digital economy development continues to progress, but the speed of development is not fast, the eastern region has the highest level of digital economy development, and the western region has the lowest ; Secondly, the development of digital economy has a bipolar development trend, the eastern region has a better development of the digital economy, and the development of the western region is relatively lagging behind; Thirdly, the development of the digital economy shows obvious regional disparities, and the disparities are most obvious in the western region, and the disparities between eastern and western regions are the most significant. The difference between the eastern and western regions is most obvious; the development of digital economy in neighbouring regions will affect each other.*

Keywords: *digital economy; regional differences; dynamic evolution*

1. Introduction

China's level of science and technology is developing rapidly, information technology is developing rapidly, data resources are improving, and with the increasing maturity of big data, artificial intelligence and other technologies, the digital economy is no longer just a concept, but is actually changing people's way of production and life. The 14th Five-Year Plan for the Development of Digital Economy makes it clear that the digital economy, as the new engine of China's economy, will enter a new phase of in-depth application, standardized development and comprehensive sharing in the next five years. The rapid development of China's digital economy will become an important engine for driving economic growth and enhancing international competitiveness.

The effect of digital economy development is remarkable, but at the same time, there are significant differences in the degree of digital economy development between regions. Due to the different development of the digital economy in each region, there are differences in the industrial structure, resulting in differences in the level of development of the digital economy in each region. The infrastructure of the eastern region is relatively more perfect, with a more developed digital industry and a stronger level of digital technology, bringing together a large number of human resources; the central region is more abundant in resources, the digital economy infrastructure is not perfect enough, the digital industry and the level of technology is developing; the western region is lagging behind in the construction of the infrastructure, there are not many digital industries, and the level of technology is relatively backward. In response to this situation, the State has clearly proposed in the "14th Five-Year Plan" to promote the development of the western region in order to form a new development pattern;

Compared with existing research, the possible innovations in this paper are: first, most of the current evaluation systems of the level of development of the digital economy are focused on the theoretical level, and there are not many differentiation analyses between regions, this paper analyses the three major economic regions in China to provide a theoretical basis for the spatial pattern of the development of the digital economy.

Second, at present, most of the research on digital economy is in the theoretical research or the research dimension is relatively single, this paper analyses the regional differences in the development of digital economy from the time dimension and spatial dimension from multiple perspectives, analyses

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the digital economy of each region more comprehensively, and provides the theoretical basis for the government to promote the synergistic development of the region.

2. Literature review

In recent years digital technology has been developing rapidly, and with it the digital economy has arisen. Digital economy is an economic form based on data resources, with the Internet as the main carrier, and is the result of the fusion of big data, artificial intelligence and the Internet. Nowadays, we are in the era of high-speed development of information, with the development of digital economy, digital information has become a key production factor throughout all walks of life.Tapscott formally put forward the concept of digital economy for the first time, and at the same time, it has a deep insight into the opportunities and challenges of economic development brought about by the era of network intelligence, which has an important significance for understanding the evolution path of the digital economy as well as the far-reaching impact on the economic landscape[1]. The concept of "digital economy" is of great significance for understanding the evolutionary path of the digital economy and its profound impact on the economic landscape. Regarding the definition of "digital economy", there are different understandings in the academic circle, some scholars believe that "digital economy" is a specific economic form, which treats goods and services as a kind of digital trade, while some scholars and institutions establish a system of indicators for the "digital economy" from the quantitative point of view. There are also some scholars and institutions from a quantitative point of view, to establish an indicator system to analyse the "digital economy", most of them use TOPSIS method, principal component analysis, entropy weight method, efficacy score method and other methods to measure the digital economy[2]. Huimei Yang et al. established a corresponding index system through digital industrialisation and industrial digitisation, and used principal component analysis to analyse the development level of digital economy in various provinces in China[3]. Di He et al. establish the evaluation system of digital economy development through the three dimensions of digital infrastructure, digital industry development and digital environment, and use the entropy weight TOPSIS evaluation method, the Moran index, and the spatial convergence model to study the level of China's digital economy development and the differences between the regional[4]. Yingjie Li et al. established an index system through the three dimensions of digital infrastructure, digital industrialisation and industrial digitisation, and used the entropy value method to measure the development trend of China's digital economy from 2010 to 2018[5]. Xiaoyi Wu et al. establish an evaluation system for inter-provincial digital economy development through the three dimensions of mobile network and talent cultivation, communication technology carrying capacity, and economic and technological foundation, and analyse the current situation of China's digital economy[6].

There are regional differences in the development of the digital economy. The research on the region of digital economy is mainly divided into two kinds, one is to study the region of China as a whole, such as the three major regions of East, Central and West; the other is to study specific regions such as the eight comprehensive economic zones, the Yangtze River Economic Belt and so on. Chenhui Ding, Di He et al. analysed China's three major regions of the East, Central and West, and found that China's digital economy has significant regional differences, overall spatial spillover effects and spatial pattern locking characteristics, the leading factor of the imbalance in the development of the digital economy comes from the inter-regional differences, the phenomenon of the regional "digital divide" is serious, presenting a East, central and western region gradient type decreasing characteristics[4,7], Luyang Tang et al. believe that China's digital economy development level is low, there is no obvious trend of progress, regional differences are large, but the overall difference is not large, the eastern region has a higher level of economic development, the central and western regions have little difference, showing the characteristics of the east is high, the central and western regions are low[8]. Yejun Yang et al. found that there are regional differences in the digital economy by studying the eight comprehensive economic zones in China, but the overall differences in the digital economy show a downward trend[9]. Maomao Ma studied the Yangtze River Economic Belt and found that there are significant regional differences in the Yangtze River Economic Belt, there is a "digital divide" phenomenon, the overall development of the digital economy in the region is slower, and the high government investment inhibits the development of the digital economy[10].

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3. Research Methodology

3.1 Development of digital economic

There is no uniform standard for measuring the development level of the digital economy, for the development level of the digital economy, two methods can be used to measure, one is to study the development level of China's digital economy by considering the value added of the information technology industry as well as the value added of the outputs of digital technology and other industries, and the other is to decompose the digital economy into different dimensions, through the construction of the digital economy indicator system, to measure the development level of China's digital economy by constructing a digital economy index system to measure[11]. The trend of change is analysed.

3.2 Selection of indicators

This paper establishes the indicator system of China's digital economy development from three dimensions, namely communication infrastructure, R&D situation and digital technology transactions, based on the principles of scientificity and data availability. Among them, digital infrastructure is an important prerequisite for the development of regional digital economy, and many scholars have chosen the dimension of digital infrastructure when studying issues related to digital economy[12]. Under this dimension, mobile Internet users, the number of IPv4 addresses and the length of fibre-optic cable lines are selected, through which the three indicators can basically understand the infrastructure construction of the digital economy. To understand the R&D situation in order to firmly grasp the initiative of the development of the digital economy, we can understand the R&D situation through the indicator of the number of effective invention patents. The development of digital industry is the core of the economic structure of the digital economy, which can directly reflect the development of a region's digital economy[4]. The development of digital industry is the core of the economic structure of digital economy, which can directly reflect the development of a region's digital economy. Under this dimension, three indicators are selected, namely IT service revenue, technology market turnover and enterprise e-commerce sales. Through the entropy value method, the seven indicators are objectively weighted, and the indicator system of China's digital economy development is finally obtained as shown in Table 1.

Table 1: Digital Economy Indicators system

dimension (math.)	norm	unit (of measure)	Indicator properties
digital infrastructure	mobile Internet user	ducal title meaning lord of 10,000 households	forward
	Number of IPv4 addresses	ten thousand	forward
	Fibre optic cable line length	kilometres	forward
Research and Development	Number of active patents	classifier for clothes, luggage, decorations; piece of work; a matter, an event	forward
Digital industry development	Income from information technology services	billions	forward
	Technology market turnover	$10,000,000	forward
	Enterprise e-commerce sales	billions	forward

3.3 Data sources and data processing

In this paper, data from the China Statistical Yearbook from the website of the National Bureau of Statistics (NBS) are selected to measure the extent of China's digital economy development from 2017-2021 for 30 provinces and regions in China, excluding Xizang, Hong Kong, China, Macao, China and Taiwan, China (Xizang, Hong Kong, China, Macao, China and Taiwan, China have a lot of missing data, so the above regions are excluded).

In order to better study the relationship between the regions, this paper divides China's 30 provinces into three major regions: eastern, central and western, according to the division criteria of the National Bureau of Statistics, based on the level of economic development, as shown in Table 2.

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Table 2: Division of China's three major economic regions

district	provinces
eastern part	Beijing, Tianjin, Hebei, Liaoning, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, Guangxi, Hainan
central section	Shanxi, Inner Mongolia, Jilin, Heilongjiang, Anhui, Jiangxi, Henan, Hubei, Hunan
western part	Chongqing, Sichuan, Guizhou, Yunnan, Shaanxi, Gansu, Qinghai, Ningxia,

4. Analysis of the development of China's digital economy

4.1 Analysis of the measurement of the level of development of the digital economy

Table 3: Level of Digital Economy Development by Province Score

district	2017	2018	2019	2020	2021	average value
Guangdong	0.644	0.670	0.683	0.704	0.703	0.681
Beijing	0.619	0.603	0.605	0.616	0.614	0.611
Jiangsu	0.455	0.484	0.447	0.470	0.436	0.458
Zhejiang	0.352	0.367	0.351	0.369	0.365	0.361
Shanghai	0.342	0.350	0.337	0.356	0.361	0.349
Shandong	0.347	0.343	0.307	0.324	0.332	0.331
Sichuan	0.262	0.267	0.277	0.278	0.271	0.271
Hunan	0.169	0.166	0.349	0.173	0.182	0.208
Hubei	0.188	0.186	0.188	0.195	0.202	0.192
Anhui	0.173	0.184	0.178	0.190	0.206	0.186
Henan	0.187	0.183	0.176	0.181	0.186	0.183
Hebei	0.164	0.177	0.176	0.182	0.179	0.176
Shaanxi	0.157	0.167	0.180	0.156	0.183	0.169
Fujian	0.165	0.165	0.153	0.141	0.140	0.153
Liaoning	0.155	0.140	0.141	0.143	0.137	0.143
Jiangxi	0.127	0.129	0.127	0.140	0.143	0.133
Guangxi	0.094	0.105	0.124	0.146	0.159	0.126
Yunnan	0.094	0.112	0.130	0.139	0.138	0.123
Chongqing	0.116	0.116	0.114	0.122	0.120	0.118
Tianjin	0.112	0.116	0.119	0.122	0.114	0.117
Shanxi	0.086	0.092	0.088	0.090	0.094	0.090
Guizhou	0.074	0.083	0.084	0.087	0.088	0.083
Inner Mongolia	0.077	0.065	0.085	0.096	0.092	0.083
Heilongjiang	0.087	0.077	0.084	0.094	0.073	0.083
Gansu	0.054	0.056	0.056	0.099	0.059	0.065
Jilin	0.054	0.071	0.063	0.066	0.051	0.061
Hainan	0.013	0.018	0.017	0.014	0.014	0.015
Qinghai	0.006	0.008	0.006	0.046	0.006	0.014
Ningxia	0.004	0.004	0.004	0.009	0.004	0.005
National average	0.181	0.186	0.191	0.193	0.191	0.188

Entropy weight-TOPSIS method is a comprehensive assessment method that combines entropy value method and TOPSIS method. Firstly, the weight of each indicator is calculated by entropy value method, and then the development of digital economy is assessed by TOPSIS method, and the comprehensive score is calculated[13]. This paper uses the entropy weight-TOPSIS method to evaluate the development of digital economy. This paper uses the entropy weight-TOPSIS method to measure the level of China's digital economy development score as shown in Table 3, the average value of China's digital economy development water was 0.181 in 2017, and it was raised to 0.191 in 2021, with an average annual growth rate of 5.4%. 2017-2021, Guangdong, Beijing, Jiangsu, Zhejiang, and Shanghai's digital economy development water the average value ranks among the top five, and the average value is above 0.34, indicating that these provinces have made more significant development achievements in the digital economy. Comparatively speaking, the three provinces of Hainan, Ningxia and Qinghai have a lower level of digital economy development, with average values below 0.02, which is a big difference from

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the regions with a high level of digital economy development. Only nine provinces have averages of digital economy development water exceeding the national average.

4.2 Spatial Markov chain analysis

Through the digital economy development level score, the differences in the development of the digital economy of each province can be seen, and the Markov chain can study the dynamic transfer characteristics of the digital economy of each region under different levels of development[14] Dynamic evolution analysis of provinces with different levels of development, classifies the 25%, 50%, and 75% nodes of the digital economy development level score of China's 30 provinces into four categories (I) of low level, lower level (II), higher level (III), and high level (IV), derives the transfer probability matrix of the digital economy development level of China's 30 provinces from 2017 to 2021.

Establish the space markov transfer probability matrix, as shown in Table 4. When the neighbouring region's digital economy development is low level (I), the probability of low level remaining unchanged is 60%, and the probability of transferring to the next level is 40%; the probability of transferring to the next level at lower level is 100%, and the probability of high level remaining unchanged is 100%. It indicates that when the neighbouring region is low level has no effect on the high level region and has the greatest effect on the lower level. When the neighbouring region's digital economy development is at a lower level (II) , the probability of the low level remaining unchanged is 88.9%, the probability of the shifting up to the next level is 11.1% ; the probability of the higher level remaining unchanged is 71.4%, the probability of the shifting down to the next level is 28.6%, and the probability of the high level remaining unchanged is 100%. The probability of remaining unchanged is 100 per cent. It means that when the neighbouring region is at a lower level, it has the greatest impact on the region at a lower level, no impact at all on the region at a higher level, and the least impact on other regions. When the neighbouring region's digital economy develops into a higher level (III), the probability on the diagonal is 50%, 100%, 100%, 100%, and the probability that the low level is transferred to the next level is 50%, indicating that when the neighbouring region is a higher level, the process of digital economy development almost always maintains the original level and has a certain driving force on the low level region.

The spatial level of digital economy development has not risen or fallen in a "cascading" manner, indicating that the development of the digital economy is relatively stable; The low and lower levels are more affected by the neighbouring regions, and when the neighbouring regions do not have a high level of development, the digital development of the low and lower level regions is unstable, especially in the lower level regions, whereas the level of digital development in the neighbouring regions will also be driven when the level of digital economy development increases; The development of the digital economy in neighbouring regions will affect each other . When the level of digital economy development in neighbouring regions increases, the level of digital development in low and lower level regions will also be driven; The development of digital economy in neighbouring regions will affect each other.

Table 4: Spatial Markov transfer probability matrix

	$t / t+1$	I	II	III	IV	observed value
I	I	0.600	0.400	0.000	0.000	5
	II	1.000	0.000	0.000	0.000	3
	III	0.000	0.000	0.000	0.000	0
	IV	0.000	0.000	0.000	1.000	1
II	I	0.889	0.111	0.000	0.000	18
	II	0.333	0.333	0.333	0.000	3
	III	0.000	0.286	0.714	0.000	7
	IV	0.000	0.000	0.000	1.000	7
III	I	0.500	0.500	0.000	0.000	4
	II	0.000	1.000	0.000	0.000	11
	III	0.000	0.000	1.000	0.000	8
	IV	0.000	0.000	0.000	1.000	4
IV	I	1.000	0.000	0.000	0.000	4
	II	0.000	0.833	0.167	0.000	12
	III	0.000	0.063	0.813	0.125	16
	IV	0.000	0.000	0.059	0.941	17

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5. Analysis of regional differences in the development of the digital economy

According to the division standard of the National Bureau of Statistics the average value of the digital economy development score of each province is classified and counted according to the three major economic regions of the east, the centre and the west, and the data in Table 5 below are obtained. As shown in Table 5, the eastern region has the highest level of digital economic development, and the western region has the lowest; the digital economic development of all three regions is getting better and better from 2017 to 2021, with an average growth rate of 2.7% in the eastern region, an average growth rate of 7.1% in the central region, and an average growth rate of 33.9% in the western region. It can be seen that the country pays more attention to the development of the digital economy. With the attention and support of the state and the government, the three major regions have been developed, especially the western region has been paid attention to and has the fastest growth rate of development.

Table 5: Mean digital economy development scores for the three economic regions

vintages	eastern part	central section	western part
2017	0.289	0.128	0.092
2018	0.295	0.128	0.100
2019	0.288	0.149	0.102
2020	0.299	0.136	0.108
2021	0.296	0.137	0.106

The Dagum Gini coefficient divides the overall regional differences into three parts: intra-regional differences, inter-regional differences, and hypervariable density, which is more accurate than the traditional Gini coefficient and Thiel index in dealing with regional imbalances[15]. In this paper, the Dagum Gini coefficient is applied to calculate the overall Gini coefficient of China's digital economy development from 2017 to 2021 as well as the Gini coefficients of the three major regions. The Gini coefficient and its decomposition results are shown in Table 6 below.

Table 6: Gini coefficient and decomposition results

vintages	G	Intraregional Gini coefficient			Interregional Gini coefficient			Contribution (%)		
		eastern part	central section	western part	east-central	east-west	China-West	regional	intra-regional	hypervariable density
2017	0.449	0.380	0.217	0.440	0.472	0.588	0.366	29.11	56.65	14.24
2018	0.440	0.379	0.214	0.414	0.474	0.566	0.344	29.35	55.97	14.68
2019	0.436	0.378	0.287	0.435	0.441	0.555	0.386	30.43	52.00	17.58
2020	0.422	0.377	0.194	0.382	0.455	0.543	0.319	29.66	55.39	14.95
2021	0.433	0.376	0.232	0.419	0.459	0.551	0.350	29.83	54.11	16.06

China's eastern, central and western regions have different fluctuation trends in the development of the digital economy within the region.In 2017-2021, the Gini coefficient in the eastern region was 0.378, the Gini coefficient in the central region was 0.229, and the average value of the Gini coefficient in the western region was 0.418, which indicates that China's western region has the largest intra-regional differences , and the central region has the smallest intra-regional differences, and the comparison with the overall Gini coefficient In terms of the overall Gini coefficient, the eastern, central and western regions are all lower than the national difference. From the overall point of view, the intra-regional Gini coefficient in China's eastern region decreased year by year from 2017 to 2021, from 0.380 in 2017 to 0.376 in 2021, the central region first increased and then decreased eventually or from 0.217 in 2017 to 0.232 in 2021, the western region first increased and then decreased from 2017 to 0.440 in 2017 to 0.419 in 2021. It can be seen that the trend in the eastern region is consistent with the whole country.

The mean values of the interregional Gini coefficients for the East-Central, East-West, and Central-West regions are 0.460, 0.561, and 0.353, and the interregional differences between the East and West regions and the East and Central regions are larger than those between the Central and West regions. The inter-regional difference between the East and Central regions decreases from 0.472 in 2017 to 0.459 in 2021, the inter-regional difference between the East and West regions decreases from 0.588 in 2017 to 0.551 in 2021, and the inter-regional difference between the Central and West regions decreases from 0.366 in 2017 to 0.351 in 2021, which can be seen as a decrease in the differences between all regions. From 2017 to 2021, the contribution rate of inter-regional differences is the highest, the contribution rate of intra-regional differences is the second highest, and the contribution rate of hypervariable density is the lowest. It can be seen that the differences in China's digital economy are mainly interregional differences between the eastern and western regions.

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6. Analysis of developments in the digital economy

In this paper, Gaussian kernel function estimation method is used to analyse the dynamics of China's digital economy development, and draw the kernel density map (Figure 1-Figure 4).

Figure 1 shows the kernel density map of China's digital economy development. The overall level of digital economy development gradually moves to the right , indicating that the development level of China's digital economy is constantly improving; The peak of the kernel density curve shows a trend of increasing first and then decreasing, indicating that the absolute gap between provinces in China's digital economy development in 2017-2021 first narrows and then expands; The existence of the kernel density curve of the digital economy has a significant right trailing feature , indicating that the gap of digital economy development among Chinese provinces is widening; the kernel density curve exists a main peak and two side peaks, indicating that the development of China's digital economy has a bifurcation phenomenon[9] , as shown in Figure 1, Figure 2, Figure 3 and Figure 4.

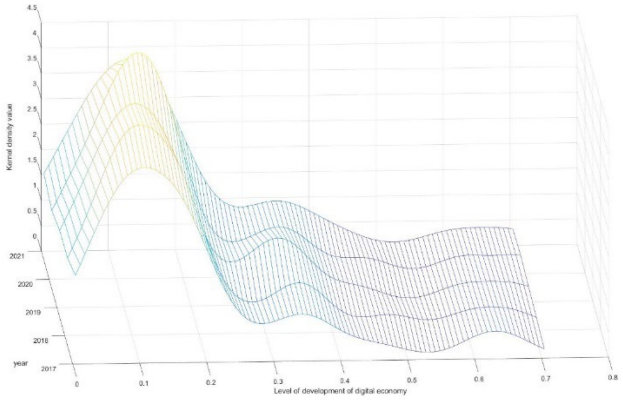

Figure 1: Kernel density map of China's digital economy development

The peak of the kernel density curve in the western region shows a trend of increasing and then decreasing, indicating that the absolute gap of digital economic development in the western region is narrowing and then expanding. The kernel density curves of the three regions have a single peak phenomenon, indicating that there is no polarisation in the development of the digital economy in the three regions.

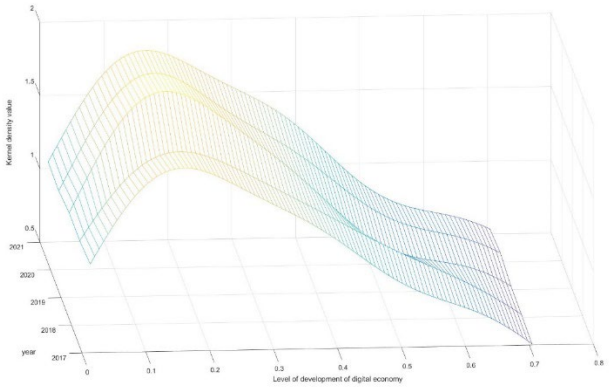

Figure 2: Kernel density map of digital economy development in the eastern region

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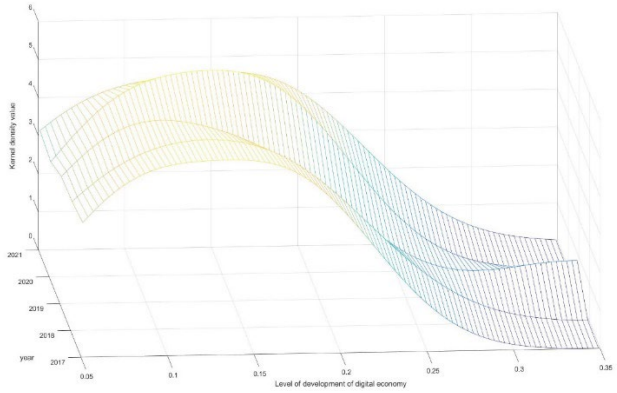

Figure 3: Kernel density map of digital economy development in the central region

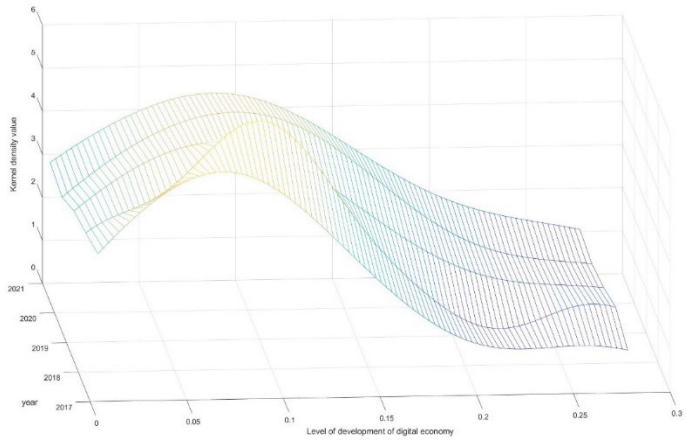

Figure 4: Kernel Density Map for Digital Economy Development in the Western Region

7. Conclusions and recommendations

Based on the relevant data from 2017-2021, this paper applies the entropy weight-TOPSIS method to study the digital economic development scores of China's provinces and rank the mean values, and applies the spatial Markov method to analyse the dynamic evolution process of China's digital economic development, and adopts the Dagum Gini coefficient to differentiate between China's east, central and west regions analysis, and use the kernel density estimation method to analyse the dynamics of China's digital economy development.

7.1 Conclusion

The conclusions of the study are set out below:

1) The level of development of China's digital economy has been progressing, but the speed of development is not fast. The eastern region has the highest level of digital economy development, and the western region has the lowest, but with the attention and support of the state and the government, all three regions have been developed, especially the western region has been paid attention to and has the fastest growth rate of development.

2) There are obvious regional differences in the level of development of China's digital economy , with the most significant differences within the western region and the smallest differences within the central region; the most significant differences between the eastern and western regions, and the smallest differences between the central and western regions; in the overall differences, the contribution rate of inter-region differences is the highest, followed by intra-region differences, and the lowest contribution rate of hyper-variable density. The differences in China's digital economy are mainly interregional differences between the eastern and western regions.

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3) The kernel density distribution curves of the whole country and the three major regions have a rightward shift, which means that the level of digital economy development has increased in all regions; the kernel density curves of the whole country and the three major regions have a rightward trailing phenomenon, which indicates that the gap between the development of the digital economy in the whole country and the three major regions has widened; the phenomenon of the co-existence of a main peak and two side seams in the whole country indicates that the development of China's digital economy is developing at a bipolar trend, and there are only one main peak in the three major regions, indicating more balanced development within the region.

4) The development of the digital economy is relatively stable and spatial shifts are not "cascading" upward or downward; the development of the digital economy in neighbouring regions affects each other; and the development of the digital economy in high-level regions is highly stable and almost unaffected by the type of spatial lag.

7.2 Recommendations

1) Strengthen the construction of digital infrastructure, especially mobile base stations, wireless networks and other infrastructure in the western region, improve the coverage of 5G networks, and enhance the transmission rate of the Internet. Ensure that digital infrastructure is in place, including high-speed and stable Internet network coverage, data centres, cloud computing services, etc., to provide a solid foundation for the development of the digital economy.

2) Reduce the gap in regional development, especially between the east and the west. The western region should learn more from the development experience of developed regions and combine it with the region's own characteristics, attract digital talents, build a demonstration zone for the development of the digital economy, and accelerate the development of the digital economy industry, and the State and the Government should pay attention to the development of the central and western regions and give them corresponding support policies and technical support.

3) Promoting Regional Synergistic Development For regions where the digital economy is relatively lagging behind, traditional enterprises should be encouraged to undergo digital transformation so as to enhance their digitalisation level. Regions with a better digital economy should continue to give full play to their advantages, actively encourage technological innovation, and increase investment in scientific research to vigorously develop digital industries, so as to drive the development of lagging regions. Strengthen inter-regional communication and exchanges, improve information-sharing capabilities, and enhance cooperation and coordination among regions. At the same time, the government should formulate corresponding development strategies, allocate more resources to the development of backward regions, and achieve coordinated regional development.

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