Research on Statistical Measurement of Digital Economy Development Level under the Background of High Quality

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Abstract: With the rapid development and popularization of digital technology, the DE(digital economy) has emerged on a global scale. The purpose of this study is to reveal the evolution trend and characteristics of DE in various regions of China from 2015 to 2022 through detailed statistical measurement. Through the extensive collection and analysis of DE index data, the spatial and temporal changes of DE are deeply explored by using KDE (Kernel density estimation)and other methods. The statistical results show that the development of DE in the eastern part of China presents obvious characteristics of left peak concentration, which shows that remarkable development results have been achieved at the beginning of the research period. Secondly, the research on the development of DE in central China reveals the trend of its single peak moving to the right, the peak value decreasing and then rising. Finally, the development of DE in western China is studied. Statistical measures show a trend of single peak moving to the right and peak decreasing, which indicates that the development of DE in this area tends to be more stable and mature. Through the statistical measurement of the development level of DE in different regions of China, this study provides a profound spatio-temporal analysis and a strong basis for policy makers to formulate more accurate and effective DE policies.

1. Introduction

The ongoing advancements in science and technology, coupled with the increasing trend of globalization, have positioned the DE(digital economy) as a pivotal driver for fostering both national economic growth and social development. As information technology undergoes rapid evolution and widespread adoption, the progress of the DE has emerged as a significant indicator of a nation's competitiveness. The robust foundation of high-quality infrastructure creates extensive room for the expansion of the DE, facilitating innovation, enhancing efficiency, and driving industrial upgrades [1].

Against the backdrop of high quality, the trajectory of DE development is shaped by a multitude of factors, encompassing but not restricted to the enhancement of information technology infrastructure, the fostering of digital talents, governmental policy support, and the augmentation of enterprise innovation capabilities. A comprehensive analysis of these elements enables a more nuanced understanding of the dynamic processes involved in DE development, facilitating the formulation of pertinent policy recommendations to propel high-quality advancements [2-3]. In reference to existing Lian Gang-hui e t al. proposes recommendations to advance the high-quality development of China's DE across four dimensions: fostering balanced industry digitalization, enhancing external openness, judiciously balancing the roles of government and the market, and concentrating on optimizing the business environment [4]. Meanwhile, Cao Zhengyong delves into the innovation components, emphasizing the substantial value derived from the integration of high-quality economic development and DE advancement [5]. Additionally, Zhou Xiaohui et al. employs comparative analysis and other methodologies to scrutinize the proportion of DE versus traditional economy in economic development. The study conducts a multidimensional investigation into the formation mechanisms of new kinetic energy in DE development and the transition from old to new kinetic energy[6].

The complexity and diversity of DE make it present diversified development levels in different countries and regions. In order to comprehensively and objectively evaluate the development level

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of DE, scientific and reasonable statistical measurement has become one of the important research directions. The purpose of this paper is to reveal the internal mechanism and influencing factors of the DE by deeply studying the statistical measurement of the development level of the DE under the background of high quality, and to provide scientific basis for decision makers and promote the sustainable development of the DE.

The research method of this paper will combine quantitative and qualitative analysis, and adopt advanced statistical technology and economic model to ensure the scientific and reliable research results. It aims to provide a comprehensive and in-depth understanding of the development level of DE under the background of high quality, provide scientific basis for relevant decisions, promote the green, intelligent and sustainable development of DE, and help build a prosperous future in the digital age.

2. Research method

2.1. Construction of evaluation index system of DE development under the background of high quality

Assessing the development of the DE in the context of high quality requires the establishment of a comprehensive and multi-dimensional index system that can precisely capture all facets of the DE [7-8]. Anchored in the essence of high-quality DE development, this study draws from the Statistical Classification of DE and Its Core Industries (2021). It expands upon the original two categories by incorporating digital foundation and digital innovation. Adhering strictly to the principles of relevance, representativeness, and availability, the study constructs an evaluative index system for DE development. This system comprises 8 first-level indicators and 17 second-level indicators, as detailed in Table 1.

Table 1 Evaluation index system of DE development

Primary index	Secondary index
Infrastructure construction and technical level	Completeness of information technology infrastructure
	technical innovation
	Application degree of artificial intelligence
Scale and growth rate of DE	Proportion of DE
	average growth rate per annum
Talent cultivation and skill level	Number of digital talents
	Digital skill penetration rate
Policy and regulatory environment	DE policy support
	Effect of innovation policy
Digital level of enterprises	Digitalization degree of enterprises
	Innovation capacity
Social participation and inclusiveness	DE participation rate
	Inclusiveness of DE
Environmental friendliness	Carbon footprint of DE
	Green technology application
Digital security and privacy protection	Digital safety index
	Privacy protection system

The establishment of such a comprehensive index system can help the government, enterprises and research institutions to fully understand the current situation and trends of the development of high-quality DE and provide strong support for formulating scientific policies and strategies. At the same time, through different levels of indicators, we can better find the problems and bottlenecks in the development of DE and provide guidance for future sustainable development.

2.2. Measure method

This paper employs the entropy weight TOPSIS method, an integrated approach that combines the entropy weight method with the TOPSIS method. Initially, the evaluation index weights are established through the entropy weight method. Subsequently, the ranking of the evaluation indices is directly determined using the TOPSIS method, leveraging specialized techniques related to the ideal solution. This approach enables an effective assessment of the relative strengths and weaknesses of each observed object, thereby enhancing the objectivity and rationality of the calculation results for the new kinetic energy index of DE development [9-10].

KDE (Kernel density estimation) is a nonparametric method for estimating probability density function. It estimates the distribution of data by placing a kernel (usually a window function, such as Gaussian kernel) around each observation and superposing the probability density at the position of each kernel. The advantage of this method is that it does not need to make any assumptions about the distribution of data, so it is very useful in dealing with complex and unknown distribution [11]. KDE is widely used in data distribution visualization, anomaly detection, statistical inference and other fields. In statistics, machine learning and data analysis, this method provides a powerful tool for better understanding data distribution and probability density.

Through this method, researchers can have a more comprehensive understanding of the distribution of the development level of the DE and identify the hot areas and possible problem areas of development. This analysis method based on KDE can provide deep insight into the development level of DE and provide scientific data support for decision makers [12].

The calculation formula of KDE is as follows:

$$\hat{f}(x)=\frac{1}{nh}\sum_{i=1}^{n}K\left(\frac{x-x_i}{h}\right) \tag{1}$$

Where: $\hat{f}(x)$ is the probability density estimate at point x . n is the number of sample observations. x_i is the observed value in the sample. $K(\cdot)$ is a kernel function, usually a symmetric function centered on the origin, such as Gaussian kernel function. nh is the bandwidth parameter, which determines the width of the kernel and affects the smoothness of the estimation.

Specifically, the Gaussian kernel function is usually defined as:

$$K(u)=\frac{1}{\sqrt{2\pi}}e^{-\frac{u^2}{2}} \tag{2}$$

In the formula, u represents the standardized variable $\frac{x-x_i}{h}$. The choice of bandwidth parameter h has a significant impact on the estimation results, which is usually determined by cross-validation or rules.

KDE estimates the probability density function of data by placing a kernel function near each observation and then superimposing them. This enables us to explore the distribution characteristics of the development level of DE nonparametric and understand the development of DE more comprehensively.

2.3. Data source

This paper focuses on the study of 30 provinces in China (excluding Hong Kong, Macao, Taiwan, and Tibet) spanning the period from 2015 to 2022. The data utilized in this research are sourced from various references, including the China Statistical Yearbook, China Information Industry Yearbook, China Science and Technology Statistical Yearbook, Peking University Digital Inclusive Finance Index, and the E-Government Research Center of the Central Party School (National School of Administration). In instances where data is missing, the linear interpolation method is employed to complete the dataset.

3. Result analysis

3.1. Measurement of the development degree of DE

Utilizing the comprehensive index system for the new kinetic energy index of DE development, this study computes the allocation levels of the three-level indicators in 30 provinces (autonomous regions, and municipalities) from 2015 to 2022. The annual average and geometric average growth rates for each province (autonomous region, and municipality), as well as the three major regions, are then calculated. This approach aims to provide a comprehensive overview of the allocation levels of the three-level indicators in the new kinetic energy index of DE development, facilitating a deeper understanding of the overall landscape.

The calculations reveal that the annual average values of fundamental kinetic energy levels in the eastern, central, and western regions are 0.0631, 0.0162, and 0.0133, respectively. Among the provinces (regions), Guangdong records the highest annual average value, while Ningxia has the lowest. In terms of technical kinetic energy levels, the annual average values in the eastern, central, and western regions are 0.0550, 0.0277, and 0.0067, respectively, with Guangdong registering the highest and Qinghai the lowest annual average values.

Moving to fusion kinetic energy levels, the annual average values in the eastern, central, and western regions are 0.0469, 0.0342, and 0.0186, respectively, with Jiangsu having the highest and Hainan the lowest annual average values. Regarding service-oriented kinetic energy levels, the annual averages in the eastern, central, and western regions are 0.0605, 0.0236, and 0.0133, respectively, with Guangdong recording the highest and Ningxia the lowest annual average values.

Lastly, for resource-based kinetic energy levels, the annual average values in the eastern, central, and western regions are 0.0456, 0.0239, and 0.0282, respectively, with Guangdong displaying the highest and Qinghai the lowest annual average values.

The analysis indicates an imbalanced regional distribution in the allocation levels of the three-tier indicators of new kinetic energy in DE development, with annual averages from 2015 to 2022 showing an order of eastern > central > western. Notably, the gap in technical kinetic energy is substantial, with the annual average in the eastern region nearly 7.3 times that in the western region. This discrepancy arises from the concentration of technological innovation primarily in a few developed areas, aiming to enhance innovation efficiency. Meanwhile, development efforts in the central and western regions are gaining momentum.

Addressing this imbalance has the potential to not only significantly boost DE development in regions with lower allocations, effectively reducing the development gap between high and low-allocated areas, and fostering a more balanced national DE development. It can also contribute to enhancing the overall national DE development level.

3.2. Analysis of the time change trend of the development degree of DE

To elucidate the comprehensive distribution and evolving trends of the new kinetic energy index levels in DE development across diverse regions and time spans in China, the nuclear density of the new kinetic energy index in various provinces (autonomous regions, and municipalities) was assessed for the years 2015 to 2022 using a spatial scale. Subsequently, a nuclear density map was generated, as illustrated in Figure 1.

From the position, the peak of the curve is at the left end, and the coverage area on the right side of the curve is obviously large, indicating that there are many high-level provinces (autonomous regions and municipalities). From the shape point of view, from 2015 to 2022, there is not much difference in the trend of curve change, which shows that the development of DE in the eastern region is relatively stable, and the internal development gap has not changed year by year.

From the position, the single peak moves left and then right, and the peak decreases and then rises, which shows that its development is unstable. From the shape point of view, the peak width of the curve decreases and the tail on both sides of the distribution increases, indicating that the gap between the new kinetic energy indexes of DE development in the central region is small, and they all show a good trend of positive growth.

From the position, the single peak moves to the right and the peak decreases, which shows that the proportion of provinces (autonomous regions and municipalities) with low-level development is decreasing and showing a positive growth trend. From the shape point of view, the peak width is obviously increased, and the tail on both sides of the distribution is aggravated, which shows that the gap between the new kinetic energy index levels of internal DE development is gradually widening.

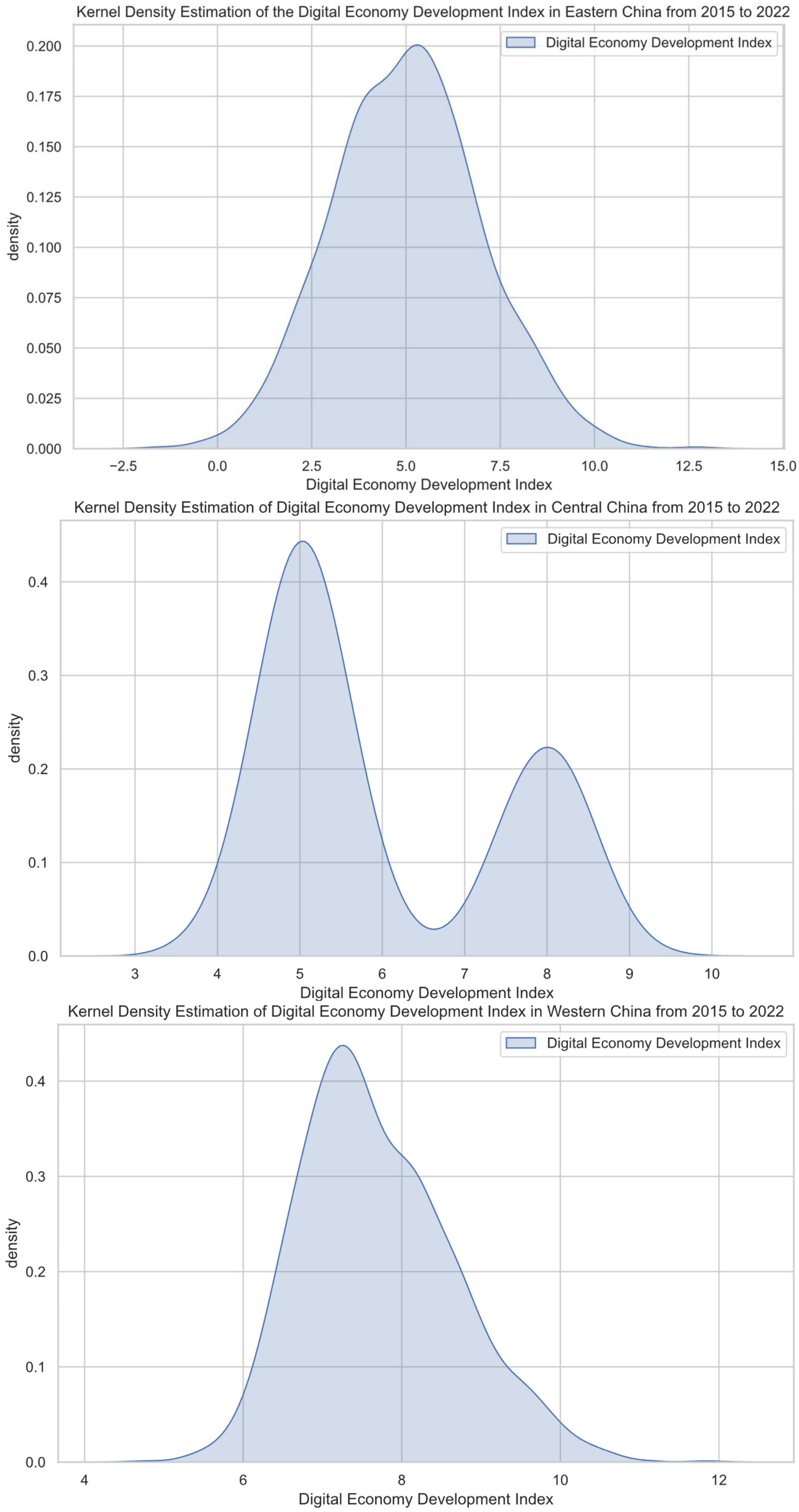

Figure 1 KDE map of new kinetic energy index level of DE development in three major regions

To sum up, the negative growth in the eastern region mostly occurs in provinces (autonomous regions and municipalities) with low internal allocation level, while the central and western regions show negative growth and positive growth trends respectively except for a few provinces (autonomous regions and municipalities), which leads to a three-step situation in the new kinetic energy of DE development nationwide.

4. Conclusions

This study found that the eastern part of China has been the leader of DE in the past few years. The DE index in this area shows the characteristics of left peak concentration in time, which indicates that the DE in the eastern part of China developed rapidly in the early stage. The development trend of DE in central China shows the characteristics of single peak moving to the right, peak decreasing and rising again. This may reflect some achievements made in the early stage of the region, and then faced some challenges or adjustments. The development of DE in western China has also been improved under the background of high quality. Statistical measures show that the single peak moves to the right and the peak decreases, indicating that the development of DE in this area tends to be more stable and mature. This may reflect the progress made in the infrastructure construction and policy support of the DE in the western region, making it maintain a relatively stable growth during the whole period. It should be noted that the development of DE is a complex process, which requires comprehensive consideration of technical, policy, social and economic factors. Future research still needs to further explore the relationship between these aspects to better guide practice and decision-making.

References

[1] Li Yong, Jiang Rui, Sharla Cheung, &Luo Lin. Measurement of high-quality development level of digital economy in China and analysis of its temporal and spatial evolution [J]. Statistics and Decision, 2023, (4), 90-94.

[2] Liu Chengkun, Jiang Yue, Zhang Qihui,&Zhu Xingfang. Statistical measurement of the development level of digital economy and research on its temporal and spatial evolution trend [J]. Industrial Technology and Economy, 2022, 41(2), 8.

[3] Lian Gang-hui, Xu Ai-ting, & Wang Wen-pu. 19 National Urban Agglomerations Digital Economy Development Level Measurement and Spatial Pattern Research [J]. Scientific and Technological Progress and Countermeasures, 2022, 39(24), 11.

[4] Xu Yinghua, &Sun Jingshu. Research on the Measurement of Digital Economy Development-Taking Gansu as an Example [J]. China Statistics, 2022, 37(9), 4.

[5] Cao Zhengyong. Research on the new manufacturing mode to promote the high-quality development of China's industry under the background of digital economy [J]. Theoretical discussion, 2018(2), 6.

[6] Zhou Xiaohui. Calculation of the integration of advanced manufacturing and digital economy: Taking the Yangtze River Delta as an example [J]. Statistics and Decision, 2021 (16), 138-141.

[7] Guo Han, Ren Baoping, & Lian Yuyan. Measurement and Analysis of China's Wealth Index under the Background of High-quality Development [J]. Economic Horizon, 2019 (2), 12.

[8] Liang Yunbao. The time essence of theft in the digital economy era. Law, 2023 (10), 77.

[9] Ma Yuefei, &Li Hai. The internal mechanism, realistic dilemma and practical path of the deep integration of cultural and sports tourism industry enabled by digital economy [J]. Journal of Shenyang Institute of Physical Education, 2023, 42(5), 108-113.

[10] Yang Shen, & Zhou Pengfei. China digital economy development level measurement and spatial-temporal pattern analysis [J]. Statistics and Decision, 2023 (3), 5-9.

[11] He Di, Zhao Xuanlong, &Qi Qi. China Digital Economy Development Level Measurement, Temporal and Spatial Pattern and Regional Differences [J]. Industrial Technology and Economy, 2023, 42(3), 54-62.

[12] Cheng Guangbin, &Li Ying. Measurement of the development level of digital economy and research on regional differences based on the technology-economy paradigm [J]. Industrial Technology Economy, 2022, 41(6), 35-43.