Study on the Regional Differences of New Quality Productivity in Various Regions of China

Abstract

This paper constructs a comprehensive evaluation index system for new quality productive forces based on three core dimensions: laborers, objects of labor, and means of production. The study emphasizes that improving new quality productive forces is a critical driver for promoting regional development and fostering balanced growth in China's national economy. Using the entropy method, it quantitatively measures the development levels of new quality productive forces across 30 provinces in China from 2012 to 2022. The selection of these 30 provinces excludes Special Administrative Regions, Autonomous Regions, and Municipalities to ensure consistency in administrative structure and data comparability. Data were sourced from official statistical yearbooks and related reports, with normalization conducted to ensure the comparability of indicators across regions and time periods. Furthermore, the Kernel density estimation method is applied to analyze spatial-temporal distribution differences and the dynamic evolution characteristics of new quality productive forces nationwide and in the three major regions: Eastern, Central, and Western China. The results indicate that the overall development level of new quality productive forces shows a continuous upward trend, albeit with significant regional disparities. The Eastern region leads significantly, driven by its strong economic foundation, policy support, and innovation-driven growth. The Central region exhibits fluctuations in certain years and provinces, but the overall development trend remains positive. The Western region has relatively low overall development levels, though provinces such as Sichuan and Chongqing show promising potential. These findings highlight the need for targeted policies to address regional imbalances and unlock new drivers of economic growth.

Keywords: New quality productive; Entropy method; Kernel density estimation;

Spatiotemporal differences; Development potential

1 Introduction

Regarding the conceptual connotation of new quality productivity, General Secretary of China first introduced the concept of "new quality productivity" during his inspection in Heilongjiang Province in September 2023. This concept emphasizes leading comprehensive industrial revitalization through technological innovation, integrating innovation resources, and guiding the development of strategic emerging industries and future industries. It represents a new concept and system for constructing China’s self-confident, independent knowledge structure in the new era.Currently, discussions on new quality productivity mainly focus on the in-depth elaboration of the two dimensions of "new" and "quality." (Zhou and Bai 2024) pointed out that new quality productivity is a newly emerging form of contemporary advanced productivity in the digital age. It is a new type of productivity born from revolutionary technological breakthroughs, innovative configuration of production factors, and the deep transformation and upgrading of industries.(Jiang et al., 2024) analyzed new quality productivity from three dimensions: new factors, new technologies, and new industries. They examined its connotation from a multi-level perspective, combining it with high-quality economic development, and proposed that it is not only the product of technological innovation but also an organic combination of industrial structure optimization and high-quality, multi-dimensional benefits.(Pan and Tao 2024) further analyzed new quality productivity from three dimensions: drive, dependence, and purpose. They argued that technological innovation is the core driving force, supported by emerging and future industries, with the goal of promoting high-quality economic development.(Zhao and Ji 2024) emphasized that the technological revolution and its resulting clusters of strategic emerging industries are the core connotation of new quality productivity. They further analyzed the critical role of new quality productivity in achieving high-quality development and enhancing social productivity.

In the study of new quality productivity, (Zhao and Liu 2024) analyzed from the perspective of new quality productivity, stating that the digital economy has significantly promoted the green transformation of resource-based industries, playing a key role by accelerating capital renewal and enhancing green technological innovation capabilities.(Gu and Tian 2024) argued that the development of new quality productivity has significantly facilitated the transformation and upgrading of the cultural industry. New quality productivity enhances the level of transformation and upgrading in the cultural industry by promoting industrial integration.(Yang and Li 2024) pointed out that new types of laborers, labor materials, and labor objects provide intellectual support, driving forces, and resource foundations, respectively, for the high-quality development of the tourism industry. Their optimized configuration injects new momentum into the tourism industry.(Qin and Jiang 2024) pointed out that the transformation and upgrading of traditional manufacturing industries are the cornerstone of building a modern industrial system. New quality productivity has become a new driving force for this transformation and upgrading, and the comprehensive integration of new factors and new technologies has improved the efficiency of resource allocation in the industrial chain, promoting the optimization of industrial chain layout and the transformation of the supply chain.(Fan et al., 2024) believes that new quality productivity is crucial for the food industry to achieve high-quality development, and proposed practical strategies for policy formulation, factor allocation optimization, industrial structure adjustment, and technological innovation, among other aspects.

In the research on the measurement of new quality productivity, scholars have established evaluation indicator systems from various perspectives.(Wang et al., 2024) constructed an evaluation indicator system for new quality productivity development level from four dimensions: technological innovation, industrial upgrading, green ecology, and integrated sharing, and used the entropy-weight TOPSIS method for measurement.(Miao et al., 2024) evaluated and analyzed the new quality productivity of cities in the Yangtze River Delta using the CRITIC-Mutation Level Method-TOPSIS.(Hu and Xu 2024) constructed an evaluation indicator system for new quality productivity based on high technology, high efficiency, and high quality.

Existing literature provides the theoretical foundation for this study, but there is still room for further research expansion.From the perspective of constructing an evaluation system, there is currently a lack of unified standards for measuring the development level of new quality productivity.Existing studies are relatively lacking in selecting relevant indicators for technological innovation and industrial upgrading, which results in an inability to comprehensively reflect the true development status of new quality productivity in China, presenting significant limitations.Moreover, existing research mainly focuses on theoretical analysis of new quality productivity, while there are deficiencies in statistical measurement and empirical analysis.This makes it difficult to achieve a detailed depiction and real-time monitoring of the development level of new quality productivity in China.Therefore, this study aims to construct an evaluation indicator system for the development level of new quality productivity and conduct empirical analysis, providing a comprehensive research framework for the academic community,and offering valuable references for the development of new quality productivity in China.

2 Research Foundation

2.1 Construction of the Evaluation Index System

By measuring the level of new productive forces, it is possible to analyze the shortcomings in the development process from an objective and multidimensional perspective.Given the accessibility of research data, this paper explores the process of constructing a comprehensive evaluation index system based on the method of (Wang and Wang 2024). This system includes three core dimensions: laborers, labor objects, and means of production, as shown in Table 1.

Table 1. New Quality Productivity Indicator System

Objective level	Normative level	Level 1 Indicator	Level 2 Indicator	Measurements and Units	Causality

		Labor skills	Per capita education level	Average years of education per capita	Positive
			Human capital structure of laborers	Divide educational attainment of the labor force into five levels, measured by vector angle	Positive
			Structure of university students	Proportion of university students to total population	Positive
	Labor	Labor productivity	Per capita GDP	GDP / Total population	Positive
			Per capita wage	Average wage of employed workers	Positive
		Labor awareness	Proportion of tertiary industry employees	Proportion of tertiary industry employees in total employment	Positive
			Entrepreneurial activity	Level of entrepreneurial activity	Positive
		New quality industry	Share of strategic emerging industries	Value-added of emerging strategic industries / GDP	Positive
			Number of robots	Number of robots / Total population	Positive
New quality productivity	Labor object	Ecological environment	Forest coverage rate	Forest coverage rate	Positive
			Environmental protection effort	Environmental protection expenditure / Government public finance expenditure	Positive
			Pollutant emissions	SO_2 emissions / GDP	Negative
				Wastewater discharge / GDP	Negative
				General industrial solid waste generation / GDP	Negative
			Industrial waste treatment	Number of industrial wastewater treatment facilities (units)	Positive
				Number of industrial waste gas treatment facilities (units)	Positive
				Treatment of industrial solid waste	Positive
	Means of production	Material means of production	Traditional infrastructure	Highway mileage	Positive
			Digital infrastructure	Railway mileage	Positive
			Digital infrastructure	Fiber optic cable length	Positive
				Number of broadband internet access ports per capita	Positive
			Total energy consumption	Energy consumption / GDP	Negative
			Renewable energy consumption	Renewable energy electricity consumption / Total electricity consumption	Positive
		Intangible	Number of patents per capita	Number of authorized patents / Total population	Positive

means of production	R&D investment	R&D expenditure / GDP	Positive
	Digital economy	Digital economy index	Positive
	Enterprise digitalization	Level of enterprise digitalization	Positive

Source: Author' s Contribution

2.2 Measurement Methods

2.2.1 Entropy Method

The index system for new productive forces covers a wide range of subdivided indicators across various types and units. Differences in units, scales, and magnitudes of these indicators may interfere with the allocation process in the comprehensive evaluation.Therefore, to ensure the validity of the results, it is necessary to carry out dimensionless quantification of the indicators.The extreme value method is used to standardize the indicator data, ensuring that the processed data values fall within the range of [0, 1], achieving data standardization and unification.The entropy weight method is used to determine the weights of the indicators for each dimension of new productive forces(Xu et al., 2024). The entropy method can overcome the interference of subjective thinking and objectively and accurately reflect the contribution of each evaluation indicator to the system.The steps are as follows:

First, the indicator data is standardized.

For positive indicators, the standardization formula is as follows:

$$X'_{ij} = \frac{X_{ij} - \min(X_j)}{\max(X_j) - \min(X_j)} \#(1)$$

For negative indicators, the standardization formula is as follows:

$$X'_{ij} = \frac{\max(X_j) - X_{ij}}{\max(X_j) - \min(X_j)} \#(2)$$

Here, X_{ij} represents the original data, i denotes the region, j denotes the indicator, X'_{ij} is the standardized result, $min(X_j)$ and $max(X_j)$ represent the minimum and maximum values of the indicator, respectively.

Next, calculate the proportional value of each sample i for indicator j:

$$P_{ij} = \frac{X'_{ij}}{\sum_{i=1}^{n} X'_{ij}} \#(3)$$

Here, n represents the total number of samples.

Then, calculate the information entropy of indicator j:

$$e_j = -k \sum_{i=1}^{n} \left(P_{ij} \cdot \ln P_{ij}\right) \#(4)$$

Based on redundancy, determine the weight of each indicator:

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j} \#(5)$$

Here, m represents the total number of indicators.

Finally, using the weighted calculation formula, the comprehensive score for each region is obtained:

$$S_i = \sum^{m} W_j \cdot X'_{ij} \#(6)$$

2.2.2 Kernel Density Estimation Method

The kernel density estimation method is used to describe the distribution and evolution patterns of regional absolute differences. This paper applies the kernel density estimation method to study the distribution, location, extensibility, and polarization trends of new productive forces and its three dimensions.Suppose $f(x)$

is the density function of China's new productive forces x:

$$f(x) = \frac{1}{Nh}\sum_{i=1}^{N} K\left(\frac{X_i - x}{h}\right)\#(7)$$

Here, N is the number of observations, x represents the mean of the observations, X_i denotes the independently and identically distributed observations ,$K(\cdot)$ is the kernel density function, and h is the bandwidth. The larger the bandwidth, the higher the estimation accuracy.This paper uses the Gaussian kernel density function to estimate the distribution dynamics of new productive forces nationwide and in the four major regions. The Gaussian kernel density function is:

$$K(x) = \frac{1}{\sqrt{2\pi}}\exp\left(-\frac{x^2}{2}\right)\#(8)$$

2.3 Data Sources

The data used in this study is sourced from the National Bureau of Statistics, the CEIC China Statistical Database, the annual official yearbooks on environment, energy, and science & technology, as well as the provincial (regional, municipal) statistical yearbooks.This paper selects data from 30 provinces (regions, municipalities) in China for the period from 2012 to 2022, considering data availability (excluding Hong Kong, Macau, Taiwan, and Tibet).In cases where data was missing for certain provinces (regions, municipalities) in specific years, interpolation methods were used to fill in the gaps, ensuring the completeness and accuracy of the data.

3 Empirical Analysis

3.1 Analysis of Measurement Results

Based on the data collection and processing mentioned earlier, and in conjunction with the constructed new quality productivity indicator system, the new quality productivity levels of 30 provinces across the country can be obtained, with the specific data shown in Fig. 1.

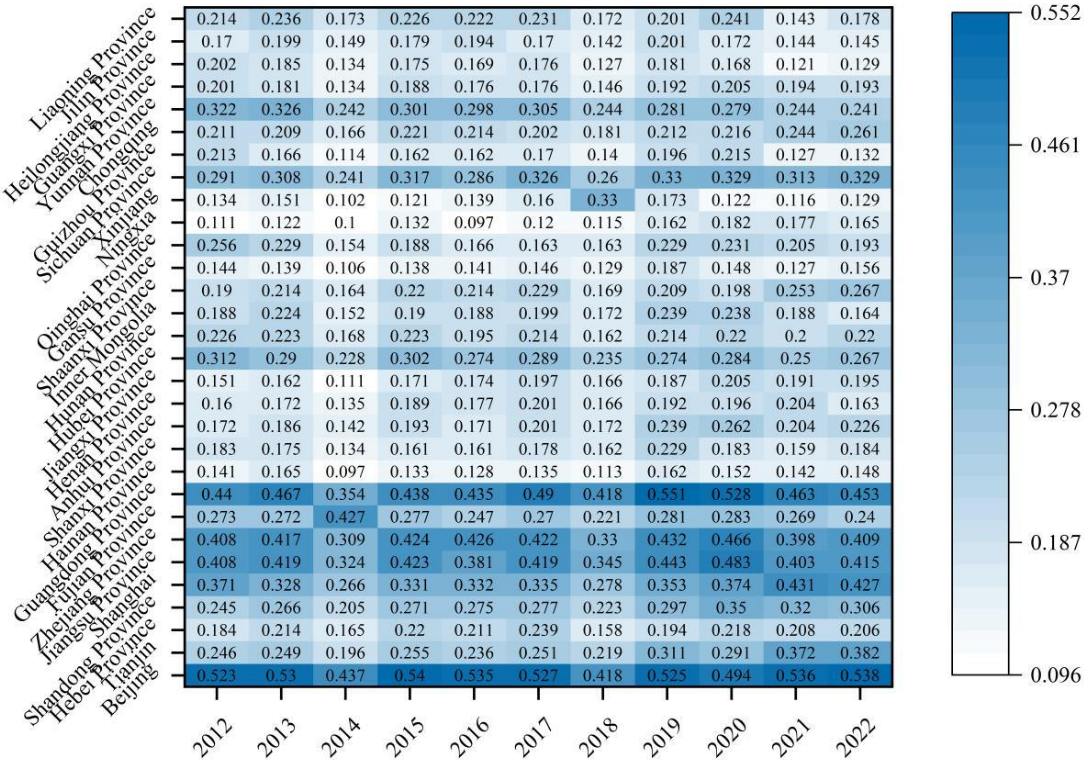


Fig.1. The level of new quality productivity

In summary, the Eastern region stands out with the highest levels of new quality productivity, marked by consistent growth in key provinces like Beijing, Guangdong, and Jiangsu, though there is some variation among other provinces. The Central region, while showing moderate productivity levels, experiences a mix of growth and stagnation across its provinces, with Anhui and Hunan showing notable improvement. The Western region, characterized by low overall productivity, exhibits significant disparities, with provinces like Sichuan showing positive growth, while others like Ningxia and Gansu remain underdeveloped. The Northeast region struggles with consistently low productivity levels and limited growth, with provinces such as Heilongjiang and Liaoning seeing a decline in recent years. Overall, the Eastern region leads, while the Western and Northeast regions face more significant challenges.

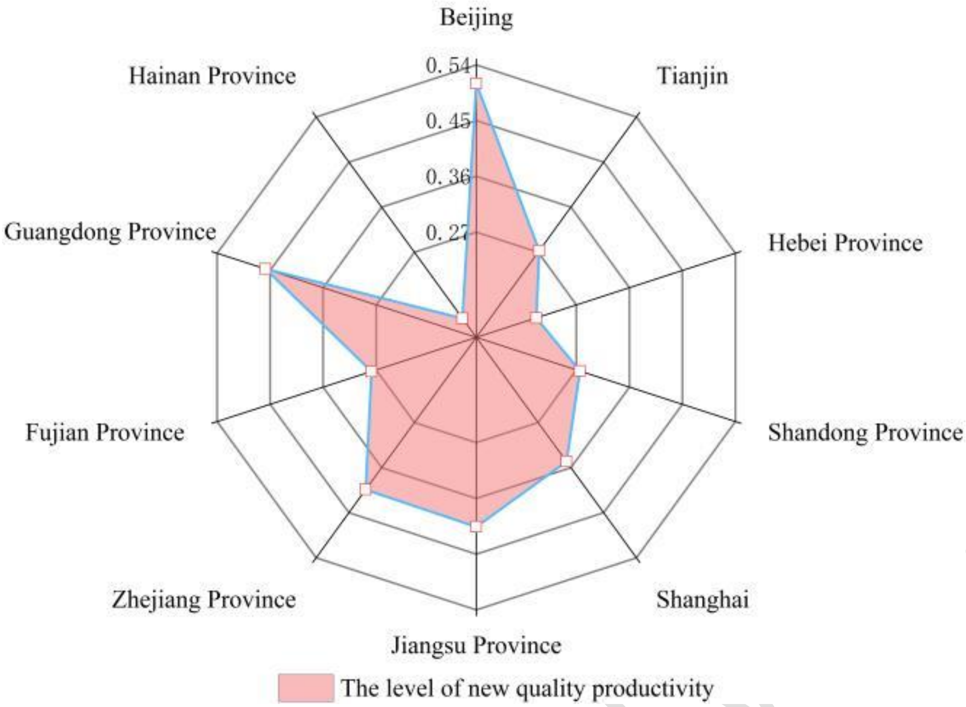


Fig.2. The Level of New-Quality Productivity in Eastern region

As shown in Figure 2, it can be seen that Beijing has the highest level of new quality productivity, reaching 0.54, far surpassing other provinces. This is primarily due to Beijing's status as the capital of China, with a strong economic foundation, advanced infrastructure, and an innovation ecosystem. As a political, cultural, and technological hub, Beijing attracts numerous high-tech companies, research institutions, and talent, and also benefits from strong government policy support. In contrast, Hainan province has the lowest level of new quality productivity at just 0.14. The low level can be attributed to Hainan's economic dependence on tourism and tropical agriculture, with a lack of high-tech industries and innovation-driven development, resulting in a slower rate of productivity growth.

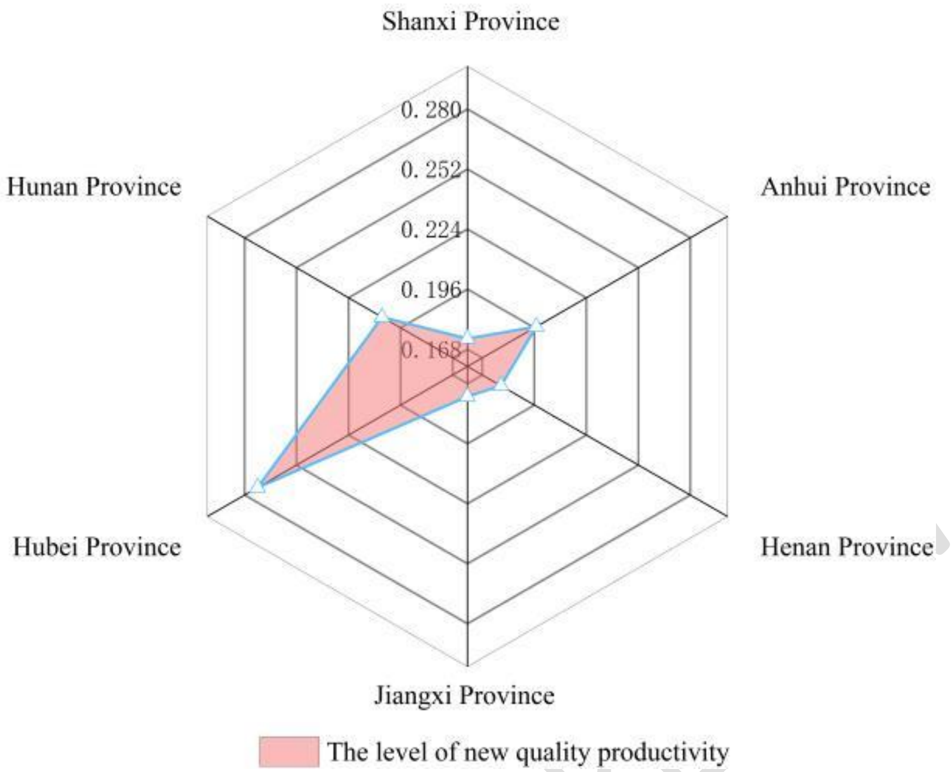


Fig.3. The Level of New-Quality Productivity in Central region

From Fig. 3, it is clear that Jiangxi Province has the highest level of new quality productivity, reaching 0.768. This stands out significantly when compared to the other provinces, such as Shanxi (0.280), Anhui (0.252), and Hunan (0.196). The higher productivity in Jiangxi can be attributed to its efforts in enhancing technological innovation and industrial upgrades, as well as regional policies aimed at attracting investments in high-tech industries. Additionally, the province has made substantial progress in improving its education and workforce skills, further driving its productivity.On the other hand, Hunan Province has the lowest level of new quality productivity. Despite being a large and populous province, Hunan's economy still relies heavily on traditional industries, with limited breakthroughs in high-tech and innovation-driven sectors. This lack of diversification in economic development contributes to the lower productivity level in the region.

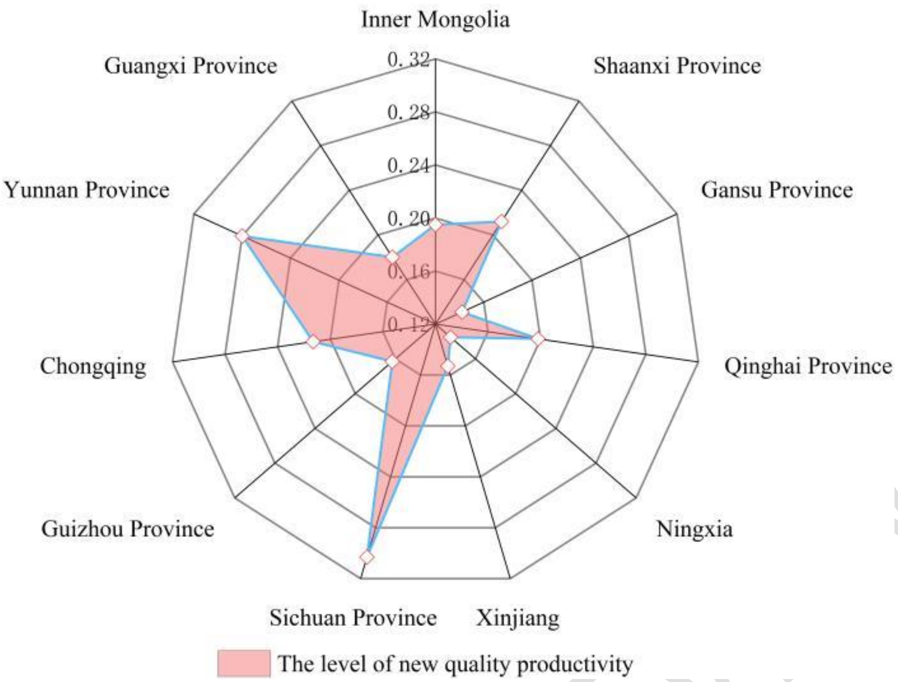
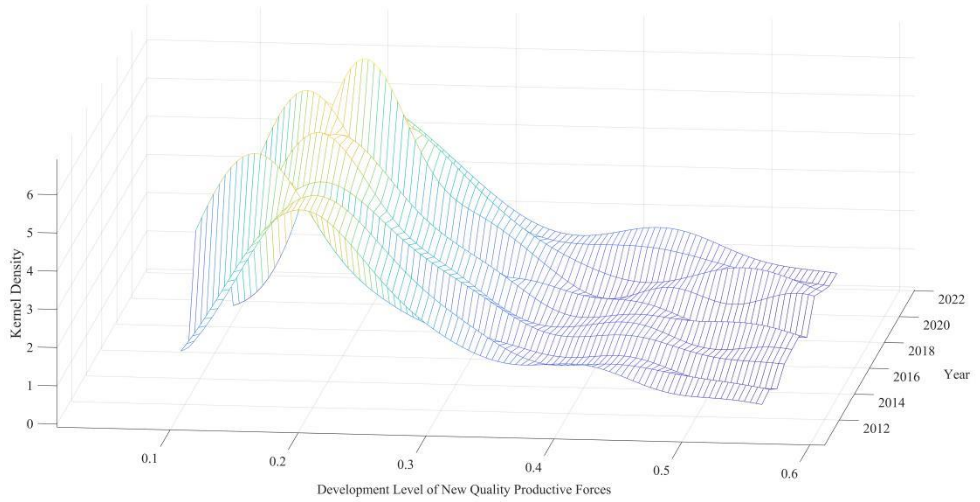


Fig.4. The Level of New-Quality Productivity in Western region

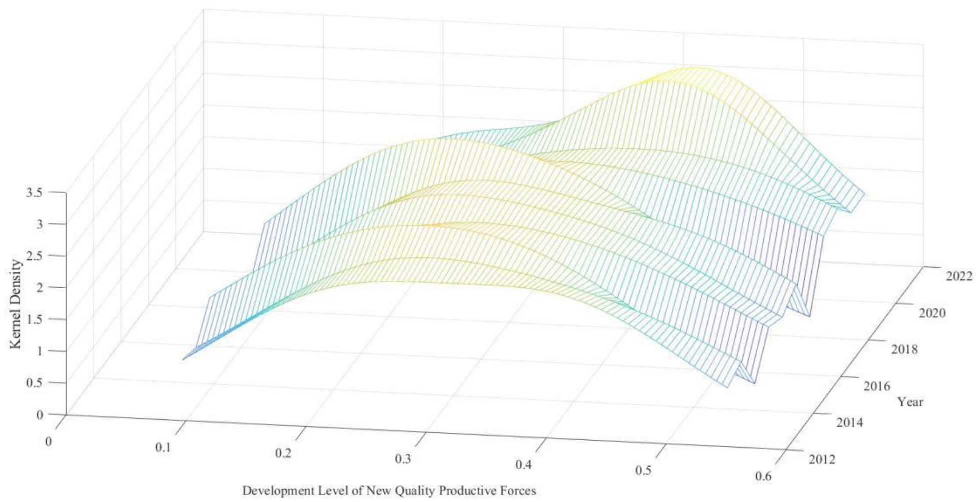
According to Fig. 4, In terms of new quality productivity, Sichuan Province stands out as the top performer.Following closely are Chongqing, with Shaanxi Province ranking third, both demonstrating strong capabilities.The advantages of these three provinces in new product quality productivity may be attributed to a combination of factors, including their geographical location, resource conditions, economic development levels, and technological innovation capabilities.In contrast, other provinces such as Inner Mongolia Autonomous Region, Gansu Province, Qinghai Province, Ningxia Hui Autonomous Region, and Guizhou Province, while showing some performance in new quality productivity, still have room for improvement.

3.2 Analysis of Dynamic Evolution Characteristics

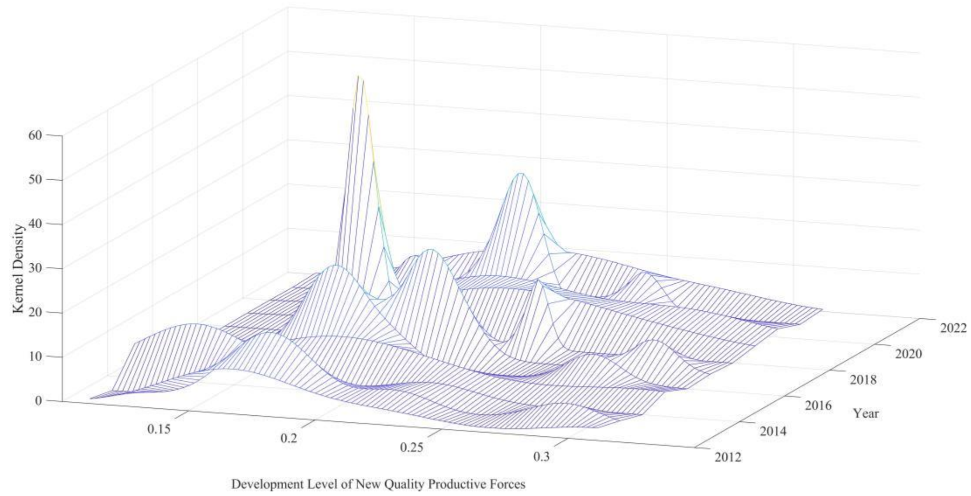
To further analyze the dynamic evolution characteristics of the development level of new quality productive forces, kernel density estimation with a Gaussian normal distribution non-parametric kernel function was applied to the observation points from 2012 to 2022. The kernel density distributions for each region are shown in Fig. 5.



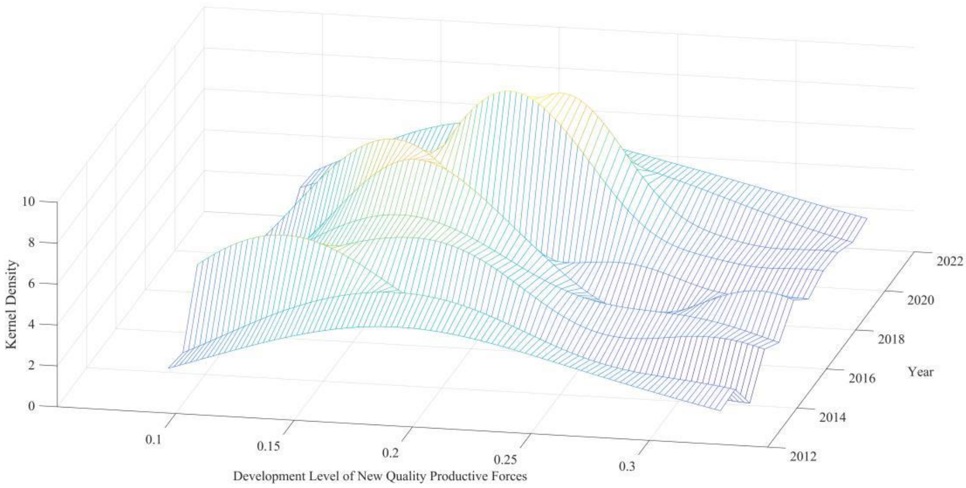
（a）Nationwide



(b)Eastern Region



(c)Central Region



(d)Western Region

Fig. 5. The Kernel Density Curve Distribution Map of New Quality Productive Forces

As shown in Figure 5（a）, between 2012 and 2022, the development level of new quality productive forces exhibited dynamic evolution characteristics.Over time, the peak of the kernel density distribution gradually shifted to the right, indicating an overall upward trend in the development level of new quality productive forces; in the early years, high-density regions were concentrated at lower levels, which later expanded toward the medium-to-high levels.Meanwhile, the width of the curve gradually expanded, indicating that the development level disparities between regions have increased, and the distribution pattern has become more dispersed.Additionally, the density peak gradually decreased, reflecting a reduction in the number of low-level development regions, and the overall distribution shows a trend towards higher-level development.Therefore, although the development level of new quality productive forces shows an overall improvement, regional imbalances still exist, requiring further efforts to promote coordinated regional development.

According to Fig. 5(b), from the perspective of the Eastern region, the development level of new quality productive forces exhibits a significant dynamic evolution trend.Overall, the peak of the kernel density distribution moves gradually to the right each year, indicating a continuous improvement in the level of new quality productive forces, with the region's overall performance increasingly aligning with higher levels.At the same time, the shape of the curve gradually widens, suggesting that the disparity in development levels between regions has increased.Furthermore, in the early years (2012), the distribution was concentrated in low-level regions, but by 2022, the distribution became more balanced, with the peak shifting towards the higher levels on the right end.

From Fig. 5(c), the development level of new quality productive forces in the Central region exhibits distinct volatility characteristics.Multiple peaks in the figure appear at different time points, especially in 2012 and 2014, indicating rapid growth in new quality productive forces in certain years.These fluctuations may reflect the impact of policy changes, technological breakthroughs, or economic environment shifts during specific periods, leading to a sharp increase in the development level of certain regions or industries.Although there is an overall upward trend, the multiple peaks in the figure indicate significant imbalances in the development of new quality productive forces between different periods and regions, particularly in lower-level regions.Moreover, the volatility in the distribution may be closely related to policy support, technological innovation, or changes in the external economic environment.Therefore, the development of new quality productive forces is driven not only by long-term trends but also by short-term factors. Future efforts should focus more on regional differences, policy guidance, and the role of technological breakthroughs in driving productive force development.

As shown in Figure 5(d), The development level of new quality productive forces exhibits significant dynamic changes across different years.Overall, the distribution curve shifts progressively from lower to higher levels. In the initial years (e.g., around 2012), the distribution was more scattered and concentrated at lower levels, whereas in later years (e.g., 2020 and 2022), the distribution curve shifted to the right and exhibited higher concentration.This change indicates that the overall development level of new quality productive forces has steadily improved over time. Simultaneously, the balance and concentration of the distribution have also significantly enhanced, suggesting that areas with high-level productive forces have gradually expanded, while low-level productivity has diminished or been optimized.

4 Conclusions and Implications

4.1 Conclusions

this paper Based on the connotation of new quality productive forces,and constructs a comprehensive evaluation index system from three dimensions: laborers, objects of labor, and means of production. The entropy method is used to measure the development level of new quality productive forces across 30 provinces in China from 2012 to 2022.Based on the measurement results, data analysis methods and the Kernel density estimation method are employed to further analyze the regional disparities and the spatiotemporal distribution evolution trends of productive forces at the national level and across the Eastern, Central, and Western regions.The main research conclusions are as follows:

First, during the observation period, the overall level of new quality productive forces in China showed a continuous upward trend, but significant regional disparities exist. From the perspective of North-South regions, the northern regions were generally slightly higher than the southern regions, with internal disparities and super-variance density being the main factors influencing the development differences between the North and the South.Among the four major regions, the development level of new quality productive forces ranks as follows: Eastern > Central > Western > Northeastern. The Eastern region maintains its leading advantage due to its strong economic foundation, technological innovation, and policy support, whereas the Northeastern region lags behind due to its rigid industrial structure and insufficient innovation vitality. Regional disparities are the main factor influencing differences in the development of new quality productive forces among the four regions.Second, the development of new quality productive forces at the provincial level in China exhibits a gradient improvement and an imbalance in development. Most provinces have achieved dynamic transitions from low to medium-low, medium-high, and eventually high levels, although some provinces remain relatively underdeveloped.Provinces such as Beijing, Shanghai, and Guangdong are at a high level of development, while certain provinces in the Western and Northeastern regions, such as Gansu, Ningxia, and Heilongjiang, remain at relatively low levels, with significant gradient differences among regions.Third, the three dimensions of new quality productive forces exhibit significant differences in their contributions. The dimensions of objects of labor and means of production contribute the most, particularly playing a crucial role in technological innovation, the development of high-tech industries, and infrastructure construction.However, the contribution of the laborer dimension is relatively low, with clear shortcomings in education levels, workforce quality, and the reserve of highly skilled talent. In some regions, a polarization phenomenon is evident, becoming a key constraint on further improvement of new quality productive forces.

4.2 Implications

(1) Optimizing Human Capital Structure

Improving the quality and diversity of the workforce is key to enhancing new quality productivity.Firstly, it is necessary to further enhance the education level of the general population, especially in the context of digital transformation. This includes promoting the diversification, personalization, and modernization of education to create a new education ecosystem driven by data and interdisciplinary integration.This not only improves the basic skills of workers but also equips them with the ability to adapt to future technological demands.At the same time, greater investment should be made in the development of a talent pipeline, particularly in foundational disciplines and areas facing talent shortages.In terms of basic disciplines, efforts should continue to advance programs for nurturing top students and enhancing innovation capabilities. In emerging and future industries, it is essential to strengthen industry-academia-research collaboration, promote the development of new engineering, new medical, and other related fields, and reinforce university-enterprise cooperation to cultivate high-end talent that meets future demands.By improving the human capital structure, the overall quality of workers at various levels can be enhanced, providing the necessary talent support for the advancement of new quality productivity.

(2) Promoting Regional Coordinated Development

Currently, there are significant regional disparities in China's new quality productivity, which hinder the process of regional coordinated development.To narrow these gaps, policy guidance should first be used to promote the orderly flow of human resources.The key to industrial transformation lies in the accompanying transfer and optimization of human resources. Special attention should be given to ensuring the rational flow of labor in regions such as the central, western, and northeastern areas, to avoid regional development imbalances caused by labor misallocation.Therefore, it is recommended to establish a system for unemployment early warning and regulation, provide diversified employment services, promote reemployment projects, and create a market-oriented employment mechanism.Secondly, long-term close cooperation between regions should be promoted, especially during the process of industrial gradient transfer, leveraging advantageous industries to achieve industry matching and upgrading.By optimizing the layout of industrial chains both within and outside regions, it is crucial to encourage regions to share development outcomes, effectively promoting the collaborative development and innovative enhancement of industries.

(3) Leveraging the Agglomeration Effect of New Quality Productivity

The development of new quality productivity is influenced by the agglomeration effect, with developed regions leveraging their efficient technological innovation and industrial clustering to drive productivity improvements in surrounding areas.To better leverage this effect, it is essential to break down barriers to the flow of factors such as talent, capital, and technology, enabling their free movement between regions.Secondly, the development of urban clusters and economic corridors should be accelerated, promoting regional coordinated development and exploring new models of regional cooperation.For example, economically developed regions such as Shanghai and Jiangsu can leverage their technological innovation advantages to drive the development of emerging industries in the surrounding central, western, and northeastern areas, thereby raising the overall productivity levels of these regions.In addition, cross-regional collaborative development should be strengthened by optimizing the layout of industrial chains and supply chains, promoting resource sharing and complementary advantages between regions.The infrastructure development between urban clusters should be strengthened, particularly in the areas of transportation, logistics, and information connectivity, to facilitate the efficient flow of economic factors across regions.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

The author(s)declare that only generative Al tools (e.g., GPT)were used for translation purposes. No generative Al technologies were employed in the writing or editing of the other content in this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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