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Dynamic evolution and regional differences of new quality productivity in China

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Abstract

An index system for inter-provincial new quality productivity in China was constructed based on the connotation of new quality productivity. The new quality productivity index was measured using the entropy method. Kernel den-sity estimation, the Theil index, decomposition, and spatial autocorrelation models were used to describe the dynamic evolution and regional differences in new quality productivity development.At the same time, this article discusses the dynamic relationship between green technology transfer and new quality productivity, as well as their coupling relationship.The results show that, from 2012 to 2022, the development level of China's new quality productivity shows an overall upward trend, and the development of new quality productivity shows significant differences among regions; the new quality productivity of each province shows an obvious trend of gradient improvement and also re-flects the characteristics of unbalanced development. There is a significant spa-tial agglomeration effect of new quality productivity, which mainly manifests as low-low agglomeration and high-high agglomeration. Based on the analysis of the coupling coordination degree in the study, it is pointed out that the effective transfer and integration of green technology can significantly promote the op-timization and upgrading of the economic structure, and enhance the level and efficiency of new quality productivity.We then put forward the policy opinions of planting high technology to promote new quality productivity, promote the coordinated development of new quality productivity in the four regions, and realize a spatial agglomeration effect on new quality productivity. This study may supplement and improve the evaluation system for new quality productiv-ity; evaluate new quality productivity by layers based on the dimensions of high technology, high efficiency, and high quality; improve the comprehensiveness and hierarchy of the index; understand the spatiotemporal evolution of China's new quality productivity; and provide new ideas for cultivating new quality productivity and promoting high-quality economic development.

Keywords

New Quality Productivity; Entropy Method; Kernel Density Estimation; Spatial Autocorrelation

1. Introduction

Amid the global scientific and technological revolution and industrial transformation, China is moving toward modernization at an unprecedented speed. New quality productivity, as the core concept in this era, not only represents the evolution direction of advanced productivity but is also a strong driving force for building a modern industrial system.

In recent years, China has made remarkable progress in emerging technologies, such as artificial intelligence, big data, and cloud computing. These technological breakthroughs not only promote changes in the production mode but also provide strong support for the development of new quality productivity. With the acceleration of scientific and technological progress and industrial upgrading, the allocation of traditional production factors, such as labor, capital, and land, is undergoing profound changes. On the one hand, a high-quality labor force has become an important force in promoting the development of new quality productivity; on the other hand, the efficiency of the use of traditional factors of production, such as capital and land, is also increasing. In addition, the rise of new production factors such as data, knowledge, and technology has injected vitality into the development of new quality productivity. Although new quality productivity has shown a vigorous development trend throughout the country, the development differences between regions remain large. Some developed regions have obvious advantages in terms of technological innovation and industrial upgrading, and the development level of new quality productive forces is relatively high. However, some less-developed areas face problems such as backward technology and a shortage of talent, and the development level of new quality productivity is relatively low. This difference in regional development not only affects the quality and efficiency of economic growth but also aggravates unbalanced development between regions.

In summary, new quality productivity is playing an increasingly important role in China's economy. With the continuous advancement of revolutionary technological breakthroughs, innovative allocation of production factors, in-depth industrial transformation and upgrading, and strengthening of policy support and guidance, new quality productivity will continue to maintain a strong development trend and promote high-quality development of the Chinese economy.

Therefore, this study focuses on the following questions. How can we accurately measure the level of development of China's new quality productive forces? What are the dynamic evolutionary characteristics of the development levels of new quality productive forces in different regions? Is the development of new quality productivity in different regions balanced, is there a significant difference, and what are the sources of this difference? What are the spatial distribution characteristics of the development of new productive forces in different regions? The answer to the foregoing questions will not only help to fully grasp the development pattern of the new quality productive forces in our country and promote the coordinated development of the new quality productive forces in various regions of China, but also help to provide an empirical basis for the analysis of the economic consequences of the new quality productive forces.

2. Literature review

New quality productivity represents the evolution of advanced productive forces. It is the quality of the advanced productive forces generated by revolutionary technological breakthroughs, innovative allocation of production factors, and deep industrial transformation and upgrading. It considers the improvement of workers, labor materials, labor objects, and their optimal combinations as its basic connotation and the substantial improvement of total factor productivity as its core symbol. The essence is advanced productive forces with strong momentum for development, which can lead to the creation of a new era of social production.

Scholars have conducted numerous theoretical discussions on the positive effects of new quality productivity on China's high-quality development. In their recent studies, Cheng and Chen [1] took the lead in emphasizing the far-reaching significance of developing new quality productivity to accelerate the process of Chinese-style modernization, which was later echoed by Gao [2]. He noted that the concept of "new quality productivity" not only provides a driving force for high-quality development in practice but also opens up a new path for accelerating the construction of a socialist political economy with Chinese characteristics at a theoretical level [2]. Zhou and Xu [3] further regard the proposal of new quality productivity as an important development and innovation of the Marxist productivity theory, emphasizing it as a key theoretical proposition for the modernization of Marxist political economy in China. They clearly point out that accelerating the formation of new quality productivity is the core driving force for high-quality development, and the two complement each other [3]. Jointly promoting sustained social and economic progress. Li and Liao [4] predicted that the trend toward new quality productivity will inevitably promote the optimization and adjustment of production relations, which is regarded as an inevitable result of historical development and provides profound insights for understanding current and future changes in social and economic structures.

The proposal and development of new quality productivity has become the focus of academic circles and has immeasurable value for Chinese modernization, high-quality development, and innovations in Marxist theory. Based on an in-depth discussion of the theory of new quality productivity, scholars have actively constructed a multidimensional and systematic index system of new quality productivity and effectively quantified its development through index dimensionality reduction technology, which provides solid support for theoretical research and practical applications. Wang and Wang [5], Han et al. [6], and Zhu et al. [7] all carefully analyzed and constructed a comprehensive evaluation index system of new quality productivity from the three dimensions of the core elements of productivity, namely, workers, labor objects, and means of production, which not only reflects a deep understanding of the connotation of new quality productivity but also reflects a comprehensive evaluation index system of new quality productivity. It also demonstrates the scientific nature and comprehensiveness of the multidimensional evaluation system.

Furthermore, Lu et al. [8], Cao and Cai [9], and Sun and Guo [10], together with other scholars, innovatively expanded the evaluation index system of new quality productivity from different value orientations and characteristics in The Times. Jiang et al. [8] emphasized the integrated role of science and technology, green productivity, and digital productivity in new quality productivity and built a comprehensive evaluation system including science and technology productivity, green productivity, and digital productivity, reflecting the diversified needs of productivity development in the new era. Cao and Cai [9] focused on the realistic background of industrial transformation and upgrading, considering information productivity, green productivity, and innovation productivity as first-level indicators, and built a new quality productivity evaluation system with the distinct brand of The Times and Chinese characteristics. Sun and Guo [10] constructed an evaluation index system from the three dimensions of scientific and technological innovation, industrial upgrading, and its development conditions and further refined the specific path and conditions for the development of new quality productivity.

These studies have enriched the theoretical connotation of the new quality productivity and provided important references for evaluating the development level of the new quality productivity, monitoring its development dynamics, and guiding the formulation of relevant policies through the construction of a specific and operable index system.

Generally, new quality productivity is an advanced productivity quality that plays a leading role in innovation; eliminates the traditional economic growth mode and development path of productivity; has the characteristics of high technology, high efficiency, and high quality; and conforms to the new development concept. "High-tech" requires attention to originality, subversive scientific and technological innovation, and integration into the whole process of production; it is the core of the formation and development of new quality productivity. "High efficiency" requires the allocation of production factors, the transformation of scientific research results, and production efficiency to reach a high level. "High quality" reflects getting rid of the traditional growth path, in line with the new development concept, more integration and new connotation, and achieving the double transcendence of "quality" and "quantity.”

In summary, many scholars' research on the development of new quality productivity is in full swing, providing certain support for quantitative research on new quality productivity. However, there is still room for in-depth research on the construction of evaluation indicators in high-tech, high-efficiency, and high-quality fields.

Accordingly, on the basis of existing research, this paper treats the provinces of China from 2012 to 2022 as research samples, takes "high-tech," "high efficiency" and "high quality" as first-level indicators, and uses the entropy method to synthesize a total index of new quality productivity by obtaining each dimension in such an index. In addition, kernel density estimation, Theil index, and decomposition were used to analyze the distribution of dynamic evolution characteristics, regional differences, and sources of the development of new quality productivity. Meanwhile, the spatial weight matrix is introduced to further characterize the spatial agglomeration characteristics of the development of new quality productivity through Moran's I calculation.

The main contributions of this study are as follows: it complements and improves the research field with the three characteristics of new quality productivity as the evaluation criteria, and describes and evaluates the development level of new quality productivity in layers based on different dimensions of high technology, high efficiency, and high quality, thus enhancing the comprehensiveness and hierarchy of the new quality productivity index. This study contributes to a deeper understanding of the spatiotemporal evolution mode of China's new quality productivity and provides innovative ideas and strategies for cultivating new quality productivity and promoting higher-quality economic development.

3. Materials and Methods

3.1 Measurement idea, index system, and data source

3.1.1. Measurement ideas

Clarifying the connotation of new quality productive forces is the basis of quantifying the development level of new quality productive forces. Based on the research of Wang and Wang [5], Han et al. [6] and Lu et al.[8], this study adopts a more acceptable definition of new quality productivity, and holds that "new quality productivity takes the improvement of workers, labor materials, labor objects and their optimal combinations as its basic connotation." In the formulation of the neoqualitative productivity category, productivity is still productivity but with a greater emphasis on "new quality," that is, relative to current and previous productivity.

The economic function of new quality productivity has been the focus of academic and practical research. Based on Wang and Wang [5] and Ren Yuxin and Wu Yan (2024), this study argues that new quality productivity, supported by traditional production factors, can play an important role in three aspects: high technology, high efficiency, and high quality.

Based on the connotation of the new quality productivity and the principle of index construction, on the one hand, the new quality productivity index should display spatiotemporal comparability, which not only reflects the trend change of the same-time dimension in the same region but also reflects the distribution characteristics of the same-time spatial dimension in different regions. On the other hand, the new quality productivity index should have multi-level characteristics, and its connotation shows that "high-tech" new quality productivity attaches importance to scientific and technological innovation, especially original and subversive innovation that integrates its achievements into the whole process of production. “High efficiency” necessitates the optimal allocation of production factors, the effective transformation of scientific research outcomes into practical applications, and the achievement of a high level of production efficiency. To achieve "high quality" on the new quality of productivity is to eliminate the traditional growth path, which is more integrated in the digital era, to better reflect the new connotations of productivity, in line with the internal requirements of high-quality development, to achieve greater "quality" and "quantity" beyond traditional productivity. Therefore, this study describes the development of new quality productivity in layers with regard to the dimensions of high tech, high efficiency, and high quality, and improves the comprehensiveness and hierarchy of the new quality productivity index.

3.1.2. Index system and data sources

The new quality productivity index system contains 21 subdivided indicators with a sample range of 31 provinces in China from 2012 to 2022 (excluding Hong Kong, Macao, and Taiwan). The data sources were the National Bureau of Statistics, China Industrial Statistics Yearbook, China Energy Statistics Yearbook, and provincial statistical yearbooks. Because of the small amount of missing original data, the missing data were processed by analogy or interpolation to reduce sample loss.

3.2 Research method

3.2.1. Entropy

The entropy method avoids the disadvantages of the subjective weighting method, and objectively reflects the importance of each index in the entire evaluation system according to the degree of dispersion of the index data. The greater the degree of dispersion, the greater the influence of the index on the evaluation system, and the greater the weight of the index. To eliminate the influence of differences in the quantity and dimension of each original index value, the original index data should be preprocessed before the index is weighted. In this study, the range standardization method was adopted to process the index data.
For positive indicators:

$$x_{ij} = \frac{x_{ij} - \min(x_j)}{max\,(x_j) - min(x_j)} \tag{1}$$

For inverse indicators:

$$x_{ij} = \frac{max(x_j) - x_{ij}}{max(x_j) - min(x_j)} \tag{2}$$

$$\omega_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$$

（3）

The information entropy, ej, of the index was calculated, where m is the number of years of evaluation.

$$e_j = -\frac{1}{\ln m} \times \sum_{i=1}^{m} \omega_{ij} \times \ln\omega_{ij} \tag{4}$$

Compute information entropy redundancy ρj:

$$\rho_j = 1 - e_j \tag{5}$$

And the desired index weight λj:

$$\lambda_i = \frac{\rho_j}{\sum_{j=1}^{m} \rho_j} \tag{6}$$

According to the index proportion ωij and the corresponding weight λj, the new quality productivity level is calculated:

$$u_i = \sum_{j=1}^{m} \lambda_j \tag{7}$$

3.2.2. Estimation of nuclear density estimation

Kernel density estimation is mainly based on the probability density function and describes the distribution characteristics of related variables through continuous smooth curves, which have less dependence on the model and strong stability. Therefore, this study analyzed the morphological characteristics of the NQPI kernel density curve at the national and regional levels through kernel density estimation to further explore the dynamic evolution characteristics of the development of NQPI in China from 2012 to 2022. The formula for kernel density estimation is as follows:

$$f(x) = \frac{1}{Nh} \sum_{i=1}^{N} K\left(\frac{x_i - \overline{x}}{h}\right) \tag{8}$$

$$K(x) = \frac{1}{\sqrt{2\pi}} exp\left(-\frac{x^2}{2}\right) \tag{9}$$

where f(x) is the density function of the random variable X, N represents the number of observed samples, and Xi refers to a series of independent congruences.

Here, X represents the mean of the observations, h is the bandwidth, K(x) is the kernel function, and the Gaussian kernel function was chosen for this study.

4. Results and Discussion

4.1 New quality productivity index measurement analysis based on advanced technology, efficiency, and quality.

According to the definition of the connotation of new quality productivity, a comprehensive evaluation index system of new quality productivity was constructed from the three dimensions of high technology, efficiency, and quality, as shown in

Table 1.

Table 1.New quality productivity index system and the weight of each index

Primary index	Secondary index	Three-level index	Measure	Weight coefficient (w)	cha
High tech	R&D investment intensity	Intensity of R&D expenditure	(industrial enterprises above designated size) R&D expenditure/GDP	2.68%	+
		R&D personnel input intensity	(industrial enterprises above designated size) R&D personnel/all employed personnel	4.18%	+
		Intensity of science and technology expenditure	Local government science and technology expenditure/fiscal expenditure	4.72%	+
	Technological innovation output	Patent applications per 10,000 people	Patent applications/population	6.61%	+
		Number of patents granted per 10,000 people	Number of patents granted/population	7.62%	+
		The proportion of high-tech industry's added value in GDP	Sales revenue of high-tech products /GDP	9.80%	+
		Share of technology market turnover	Technology market turnover/Gross regional product	10.16%	+
	High-tech industry development	Exports of high-tech products	Revenue from export sales of high-tech products	11.77%	+
		High-tech industry scale	Number of high-tech enterprises	9.93%	+
		Benefit of high-tech industry	High-tech industry profit rate = total profit/main business income	2.44%	+
	Scientific and technological talent reserve	R&D personnel per 10,000 full-time equivalent	Full-time equivalent of R&D personnel/population	5.75%	+
High effect	Efficiency of energy use	Energy intensity per GDP	Total energy consumption /GDP	0.90%	-
	labo(u)r productivity	Pers Personnel labo labor productivity	GDP/ Number of employees	3.18%	+
	management efficiency	Administrative expenses as a proportion of corporate profits	Overheads/total business profits	0.05%	+
High quality	Quality of products	Quality pass rate of main industrial products	Industrial product quality pass rate data	0.71%	+
	Quality of economic operation	Increasing rate of GDP	GDP growth rate	0.45%	+
		Industrial structure optimization rate	The proportion of tertiary industry	2.00%	+
	Ecological environment quality	Environment pollution treatment	Investment in industrial pollution control (ten thousand yuan)	5.94%	+
	Quality of social development	Educational level	Number of graduates from regular institutions of higher learning (10,000)	3.62%	+
		Medical care level	Number of health technicians per 10,000 people	1.47%	+
			Health insurance participation rate	2.84%	+
		Residents' income level	Per capita disposal income	3.17%	+

4.2 Analysis of new quality productivity index measurement results

4.2.1.Measurement results of new quality productivity

Based on the previous data collection and processing, the new quality productivity levels of the 31 provinces in China can be obtained according to the constructed new quality productivity index system, as shown in Table 2. In terms of growth rate, since 2012 the level of new quality productivity in all provinces has increased; Jiangxi Province has the highest growth rate (up to 2.21%), and Tianjin has the lowest growth rate (0.18%). From an average perspective, regional development is quite different. The development level of new quality productivity in Guangdong Province is the highest in China (0.5201), whereas that in Qinghai Province is the lowest (0.1044).

Table 2.Measurement results of new quality productivity in 31 provinces from 2012 to 2022

Region	Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	mean value	growth rate
Nationwide	mean value	0.1487	0.1612	0.1698	0.1771	0.1859	0.2004	0.2167	0.2225	0.2396	0.2610	0.2685	0.2047	0.8059
	Beijing	0.3115	0.3370	0.3397	0.3321	0.3458	0.3639	0.3873	0.4108	0.4534	0.5214	0.4984	0.3910	0.6001
	Tianjin	0.2988	0.3478	0.3675	0.3854	0.3634	0.3228	0.3371	0.3105	0.3431	0.3690	0.3539	0.3454	0.1845
	Hebei	0.0994	0.1171	0.1388	0.1279	0.1458	0.1607	0.1960	0.1814	0.1875	0.1994	0.2200	0.1613	1.2140
	Shanghai	0.2594	0.2564	0.2617	0.2769	0.3064	0.3120	0.3121	0.3255	0.3551	0.3927	0.4076	0.3151	0.5716
	Jiangsu	0.4228	0.3848	0.3921	0.4122	0.4352	0.4118	0.4499	0.4867	0.5464	0.5689	0.5764	0.4625	0.3632
East	Zhejiang	0.2531	0.2933	0.3039	0.3212	0.3361	0.3372	0.3729	0.4004	0.4459	0.4695	0.5043	0.3671	0.9924
	Fujian	0.1826	0.1855	0.1834	0.2034	0.2092	0.2241	0.2459	0.2533	0.2826	0.3142	0.3155	0.2363	0.7281
	Shandong	0.2022	0.2183	0.2450	0.2538	0.2776	0.2820	0.2654	0.2735	0.2871	0.3363	0.3734	0.2740	0.8466
	Guangdong	0.4063	0.3990	0.4227	0.4341	0.4755	0.5283	0.5381	0.5747	0.6260	0.6706	0.6454	0.5201	0.5883
	Hainan	0.0930	0.0953	0.0974	0.0967	0.0995	0.1006	0.1212	0.1318	0.1226	0.1393	0.1489	0.1133	0.6001
	Regional mean	0.2529	0.2635	0.2752	0.2844	0.2994	0.3043	0.3226	0.3349	0.3650	0.3981	0.4044	0.3186	0.5989
	Shanxi	0.0942	0.1269	0.1000	0.0965	0.0988	0.1355	0.1382	0.1441	0.1416	0.1453	0.1623	0.1258	0.7228
	Anhui	0.1387	0.1541	0.1558	0.1723	0.2077	0.2106	0.2537	0.2556	0.2900	0.3365	0.3534	0.2299	1.5489
	Jiangxi	0.0851	0.0973	0.1036	0.1109	0.1256	0.1641	0.1983	0.2253	0.2483	0.2559	0.2734	0.1716	2.2131
midland	Henan	0.1100	0.2110	0.2315	0.2453	0.2554	0.2879	0.2976	0.2615	0.2768	0.2952	0.3034	0.2523	1.7575
	Hubei	0.1293	0.1436	0.1601	0.1603	0.1849	0.2075	0.2215	0.2371	0.2553	0.2841	0.3143	0.2089	1.4306
	Hunan	0.1178	0.1277	0.1376	0.1516	0.1473	0.1795	0.2001	0.2099	0.2309	0.2537	0.2809	0.1852	1.3856
	Regional mean	0.1125	0.1435	0.1481	0.1562	0.1699	0.1975	0.2182	0.2223	0.2405	0.2618	0.2813	0.1956	1.5002
	Inner Mongolia	0.1089	0.1141	0.1224	0.1134	0.1154	0.1326	0.1289	0.1406	0.1295	0.1484	0.1515	0.1278	0.3912
	Guangxi	0.0799	0.0880	0.0926	0.0958	0.0967	0.1247	0.1288	0.1328	0.1362	0.1721	0.1652	0.1194	1.0661
	Chongqing	0.1234	0.1332	0.1646	0.2280	0.2010	0.2443	0.2216	0.2247	0.2528	0.2786	0.2833	0.2141	1.2947
	Sichuan	0.1028	0.1087	0.1209	0.1235	0.1385	0.1597	0.1865	0.1949	0.2071	0.2216	0.2241	0.1626	1.1796
	Guizhou	0.0650	0.0733	0.0948	0.0974	0.0861	0.1002	0.1389	0.1424	0.1523	0.1539	0.1626	0.1152	1.5033
	Yunnan	0.0703	0.0784	0.0805	0.0859	0.0872	0.1150	0.1246	0.1354	0.1443	0.1503	0.1571	0.1117	1.2355
west	Xizang	0.0754	0.0745	0.0750	0.0862	0.0895	0.1003	0.1290	0.1252	0.1298	0.1403	0.1385	0.1058	0.8374
	Shaanxi	0.1195	0.1360	0.1452	0.1544	0.1529	0.1581	0.1834	0.1980	0.2046	0.2243	0.2369	0.1739	0.9825
	Gansu	0.0797	0.0833	0.0877	0.0899	0.0961	0.1220	0.1245	0.1264	0.1307	0.1408	0.1472	0.1117	0.8481
	Qinghai	0.0772	0.0837	0.0871	0.0897	0.1001	0.1179	0.1234	0.1102	0.1128	0.1237	0.1231	0.1044	0.5937
	Ningxia	0.0868	0.0913	0.1031	0.1026	0.1190	0.1267	0.1351	0.1358	0.1433	0.1640	0.1612	0.1244	0.8577
	Xinjiang	0.0812	0.0949	0.0952	0.0906	0.0935	0.0951	0.1219	0.0979	0.1155	0.1306	0.1415	0.1053	0.7433
	Regional mean	0.0892	0.0966	0.1058	0.1131	0.1147	0.1331	0.1455	0.1470	0.1549	0.1707	0.1743	0.1314	0.9552
	Liaoning	0.1328	0.1425	0.1478	0.1333	0.1411	0.1472	0.1669	0.1692	0.1809	0.1971	0.2033	0.1602	0.5303
	Jilin	0.0933	0.0981	0.1037	0.1085	0.1163	0.1233	0.1411	0.1485	0.1537	0.1511	0.1491	0.1261	0.5981
northeast	Heilongjiang	0.1093	0.1014	0.1026	0.1087	0.1149	0.1174	0.1293	0.1328	0.1422	0.1423	0.1486	0.1227	0.3599
	Regional mean	0.1118	0.1140	0.1180	0.1168	0.1241	0.1293	0.1458	0.1502	0.1589	0.1635	0.1670	0.1363	0.4936

Based on the entropy method and data processing above, new quality productivity index measurement results were obtained for 31 provinces in China from 2012 to 2022. Figure 1 shows the changing trends of the new quality productivity index at the national and regional levels in the eastern, central, western, and northeastern regions of China. Overall, whether at the national or regional level, new quality productivity showed a rapid growth trend, which slowed after 2018 despite maintaining steady growth. The likely reason for this is that the COVID-19 pandemic had a severe negative impact on productivity in 2019 and beyond, where production and supply chain disruptions, labor shortages, reduced capacity, and reduced willingness to consume combined to reduce production capacity worldwide. From the perspective of regional differences, the development of new quality productivity shows a staircase development of east-west-Midland-northeast. The development level of new quality productivity was the highest in the eastern region, followed by the western, central, and northeastern regions.

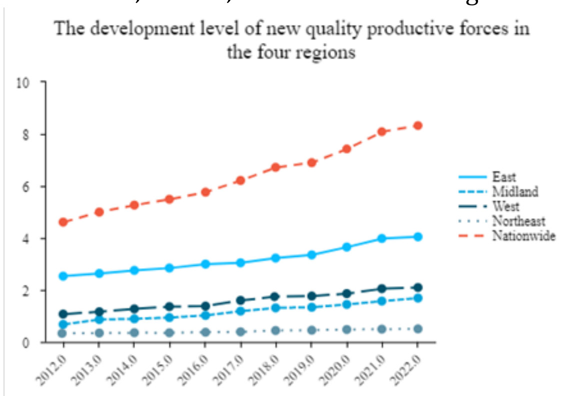

Figure 1. The development level of new quality productive forces in the four regions

In addition, the new quality productivity index for major years in each region were analyzed, as shown in Figures 2 and 3. It can be found that Guangdong, Jiangsu, Zhejiang, Beijing, and Shanghai have always occupied the leading position in the development of new quality productivity in China. Since 2022, Anhui, Guangdong, Hubei, and Hunan have caught up and pursued new quality productivity development, whereas the development of new quality productivity in other provinces remains in a relatively backward position.

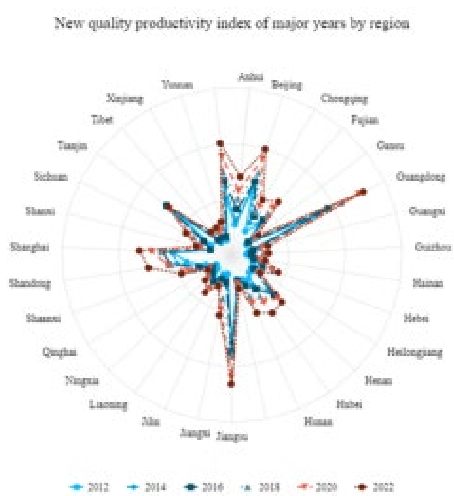

Figure 2. New quality productivity index of major years by regions

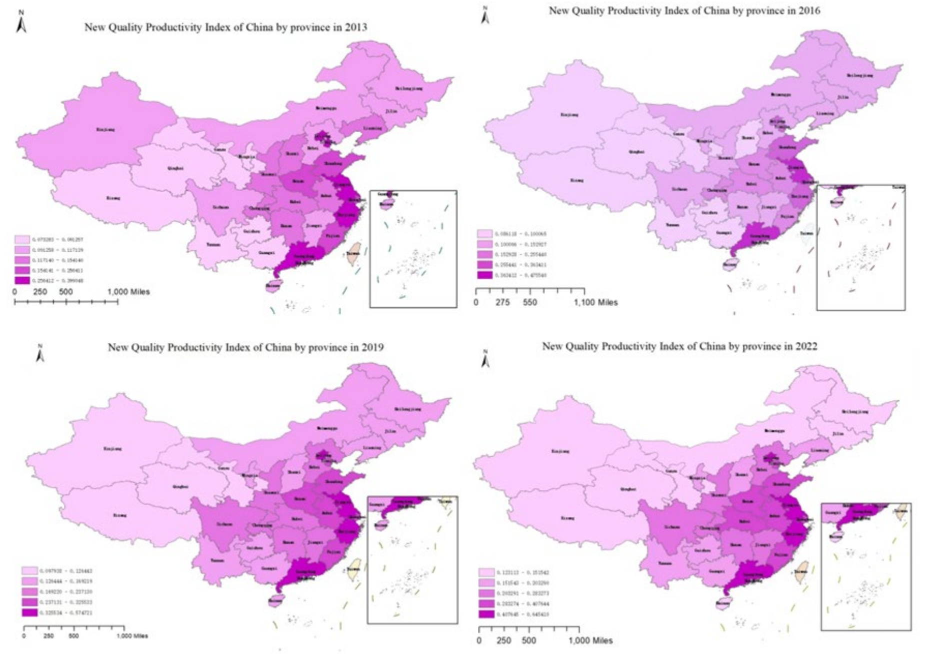

Figure 3. New quality productivity index of major years by regions

4.2.2. Characteristics of the dynamic evolution of the development of new quality productive forces

Based on the relevant features of the obtained kernel density curve (location, shape, ductility, etc.), the dynamic evolutionary characteristics of new quality productivity development from 2012 to 2022 were analyzed at the national level. Figure 4 shows the dynamic distribution of new quality productivity development across the country from 2012 to 2022. From the perspective of the distribution position of the curve, the distribution curve of the development of new quality productivity in each period shows a trend of gradually shifting to the right, indicating that its development level is improving year by year. During the sample period, the growth rate of China's new quality productivity can be roughly divided into two stages, namely, 2012–2017 (Fig. 5) and 2018–2022 (Fig. 6). During 2012–2017, the growth rate of new quality productivity showed a rapid growth trend; the growth rate continued to increase, and the development rate became relatively stable in 2018. Although the growth rate slowed, it maintained a steady growth trend.

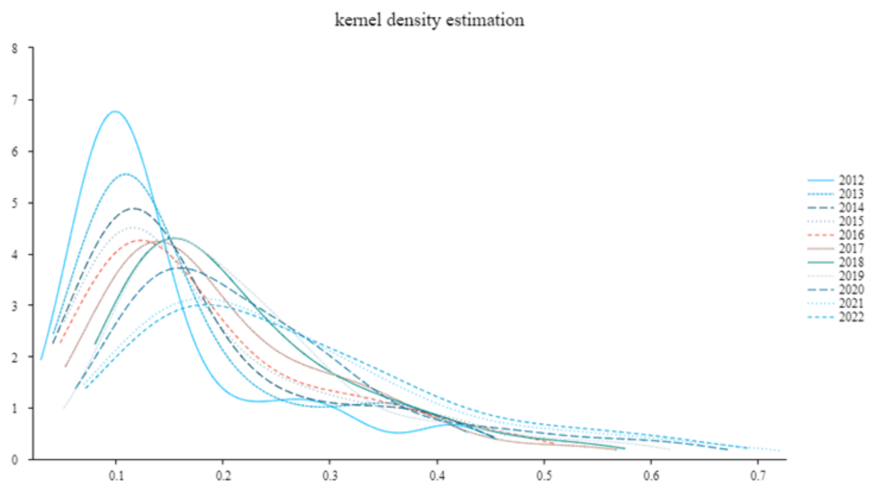

Figure 4. Kernel density estimation of 2012--2022

Furthermore, the figure were used to analyze the morphological characteristics of the new quality productivity distribution curve for each period. From the perspective of the changes in peak height and width, the peak height of the distribution curve during the sample period presents a trend of "substantially decreasing - slightly decreasing," while the peak width presents a trend of "significantly expanding - slightly expanding," indicating that the absolute difference in the development of new quality productivity increased rapidly during the sample period from 2012 to 2017. The absolute difference in the development of new quality productivity still shows an expanding trend, but the rate of expansion has slowed down although a significant expansion effect was maintained. Regions with advanced new quality productivity can drive the development of those with a backward new quality productivity. From the perspective of the distribution and ductility of the curve, the distribution curve showed a trend of "obvious widening - slight widening." From 2012 to 2017, the ductility of the distribution curve of new quality productivity widened significantly, and the right-trailing phenomenon was prominent, indicating that the difference in the development level of new quality productivity between regions increased during the sample period. From 2018 to 2022, the ductility of the distribution curve shows a slightly widening trend, and the widening speed of the gap between regions with high new quality productivity and regions with low development levels decreases. From the perspective of peak form and number of the distribution curves, the distribution curve of new quality productivity presents the fluctuation characteristics of "bimodal, unimodal and multimodal." From 2012 to 2017, the distribution curve of new quality productivity transitioned from multimodal to unimodal, and the polarization phenomenon gradually weakened. From 2018 to 2022, the distribution curve presented a unimodal evolutionary trend with almost no lateral peaks. It shows that with the continuous development of new quality productivity, its development appears a slightly multi-polarized phenomenon, and a few areas have reached a higher level of development.

5. Conclusion and policy recommendations

5.1 Conclusion

Based on the characteristics of new quality productivity, this study constructs a comprehensive evaluation index system of new quality productivity from the three dimensions of high technology, high efficiency, and high quality and adopts the entropy method to measure the development level of new quality productivity in 31 provinces in China during 2012–2022. Given the measurement results, the kernel density estimation method, Dagum Gini coefficient method, and spatial autocorrelation model were used to further analyze the dynamic evolution and regional differences in the development level of new quality productivity in the country's four regions.

The main conclusions are as follows:

First, during the sample period, the overall development level of China's new quality productivity showed an upward trend, and the development of new quality productivity showed significant regional differences. From the perspective of the four regions, the development level of new quality productivity was in the order of eastern > western > central > northeast region, and regional gap was the main factor affecting the development of new quality productivity in the four areas.

Second, the provinces in the new quality productivity showed a clear gradient trend of improvement but also reflected the characteristics of unbalanced development. Specifically, many provinces experienced a dynamic development process from the initial low-level stage, gradually maintaining a low level, jumping to a higher level, and finally reaching a high level.

Third, there is a significant spatial agglomeration effect of new quality productivity, which manifests mainly as low-low and high-high agglomeration.

5.2 Policy recommendations

Based on these findings, the following policy recommendations are put forward:

In the one hand, the research shows that of the three characteristics of new quality productivity, the contribution of high technology to the improvement of new quality productivity ranks highest, and the contribution of the high-efficiency dimension ranks lowest. In the context of high-quality development, planting advanced technology to drive high efficiency and improve new quality productivity is the key to promoting sustainable and healthy economic and social development. The following policy recommendations aim to enhance new quality productivity through technological innovation. First, we should increase the construction of a scientific and technological innovation system, increase the proportion of R&D investment in GDP, encourage diversified participation, optimize the layout of scientific research, strengthen the combination of basic and applied research, and strengthen intellectual property protection to stimulate innovation. Second, it promotes the development of high-tech industries, formulates clear industrial development plans, supports the growth of innovative enterprises, and promotes collaborative innovation upstream and downstream in the industrial chain to enhance industrial competitiveness. In addition, we should deepen the reform of the scientific and technological system, reform the talent evaluation mechanism, optimize the transformation mechanism of scientific and technological achievements, and strengthen international cooperation in science and technology to enhance our country's position in the global competition in this field.

In the other hand, it promotes the coordinated development of new quality productive forces in the four regions, narrows the regional development gap, and achieves sustained and healthy development of the national economy. The eastern region will continue to play a leading role in strengthening innovation-driven development, deepening the reform of the scientific and technological innovation system, increasing investment in R&D, promoting the development of high-end manufacturing and modern service industries, and building a global scientific and technological innovation highland. The western region will increase support, improve the level of basic public services, guide the flow of production factors, strengthen infrastructure construction, and promote leapfrog development. The central region undertakes industrial transfers, promotes industrial agglomeration and upgrading, strengthens the construction of city clusters, and enhances industrial competitiveness. The northeast region has deepened reform, stimulated market vitality, developed modern agriculture and green industries, strengthened international cooperation, and accelerated the pace of revitalization. At the national level, regional policy coordination should be strengthened, regional cooperation mechanisms established and improved, and coordinated development of the four regions should be promoted.

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