

Analysis of Collaborative Measurement and Spatial Differentiation Characteristics of Provincial-Level Green Economy and New Quality Productivity in China

Jiayan Han*

School of Mechanics and Civil Engineering, China University of Mining and Technology, Xuzhou, China, 221116

*Corresponding author: 02234241@cumt.edu.cn

Abstract. This study aims to construct a comprehensive evaluation framework for green economy and new quality productivity, systematically assessing their development levels and spatial differentiation characteristics. Based on multi-attribute comprehensive evaluation theory, indicator systems were developed for green economy (comprising three primary indicators: low-carbon development, ecological benefits, and economic level) and new quality productive forces (comprising three primary indicators: laborers, objects of labor, and means of labor). The Entropy Weight-TOPSIS method was applied to dynamically measure China's provincial administrative units, aiming to overcome limitations of traditional subjective weighting approaches. Empirical results indicate that the national green economy index steadily increased from 0.281 to 0.302 between 2015 and 2022, reflecting positive synergies between economic growth and environmental sustainability. However, both green economic development and new-quality productive forces exhibit pronounced regional gradients. Eastern coastal regions maintain a leading position through synergistic advantages in industrial structure, technological innovation, and institutional efficiency. Central regions face the dual squeeze of industrial relocation and traditional resource dependency, becoming transition troughs in green development. Western regions exhibit a unique pattern of simultaneous potential release and overall lag, possessing strategic buffer space based on ecological carrying capacity. New-type productive forces also exhibit spatial differentiation characterized by higher levels in the east and lower levels in the west. The long-term gap between the national average and the median reveals uneven regional development, reflecting a coexistence of leading heads and long-tail catch-up.

Keywords: Green economy; New quality productivity; Entropy-Weighted TOPSIS.

1. Introduction

Against the backdrop of intensifying global climate change, China's 2020 dual carbon strategic goals signaled a systemic shift in economic development from traditional factor-driven to innovation-driven models. Against this backdrop, the green economy provides a practical vehicle for economic transformation through efficient resource utilization and the restructuring of environmentally friendly industries. Meanwhile, new-quality productive forces, centered on innovation-driven development, propel a qualitative leap in productivity. The synergistic development of these two approaches has become the key pathway to resolving the growth-emission reduction paradox. However, existing research exhibits significant shortcomings at both theoretical and practical levels. Current evaluation systems often compartmentalize the intrinsic link between the green economy and new-quality productive forces, lacking a comprehensive indicator framework that reflects their synergistic mechanisms. Furthermore, analyses of regional development disparities frequently remain at the surface level of geographical segmentation, insufficiently deconstructing deep-seated drivers such as industrial structure rigidity and policy response efficiency[1-2]. Against this backdrop, the core research question is: How can a scientific, comprehensive evaluation framework be constructed to quantify the level of synergistic development between the green economy and new-quality productive forces at China's provincial administrative units, driven by global climate change and the dual carbon goals? How can this framework systematically deconstruct the significant regional differentiation characteristics in their spatiotemporal evolution and the underlying deep-seated driving mechanisms?

Employing an interdisciplinary approach, this study aims to construct a comprehensive evaluation framework for green economy and new-quality productive forces, systematically assessing their development levels and spatial differentiation characteristics. Breaking from traditional single-dimensional analysis paradigms, this study innovatively integrates the Entropy Weight-TOPSIS model to systematically measure the development levels of the green economy and new-quality productive forces nationwide. It focuses on revealing the spatial gradient characteristics in development levels and driving mechanisms across eastern, central, and western regions through spatiotemporal comparisons and factor decomposition, providing empirical evidence for formulating differentiated development strategies[3].

2. Indicator System and Measurement Method of Green Economy and New Quality Productivity

The comprehensive evaluation of green economy and new quality productivity relies on multi-attribute analysis methods, and its process includes four core steps: evaluation system construction, data processing, weight determination, and method selection. Existing studies have formed a mature framework in the measurement of high-quality development, common prosperity, and Chinese-style modernization, providing theoretical support and perspective reference for this study. Based on this, this paper constructs a comprehensive evaluation system covering 3 first-level indicators and 6 second-level indicators, and uses the entropy weight-TOPSIS measurement method to assign weights to the indicators, thereby systematically measuring the development level of green economy and new quality productivity nationwide, obtaining the index ranking of each region, and further analyzing the development status of green economy and new quality productivity in each region[4-5].

2.1. Evaluation Index System of Green Economy and New Quality Productivity

As shown in Table 1, the evaluation of green economy in this paper is mainly based on 3 first-level indicators: low-carbon development, ecological benefit, and economic level.

Table 1 Evaluation Index System of Green Economy

First-level Indicator	Serial Number	Second-level Indicator	Unit	Attribute
Low-carbon Development	A1	Industrial Wastewater Discharge/Gross Domestic Product	%	-
	A2	Comprehensive Utilization Volume of Solid Waste / Generation Volume	%	+
Ecological Benefit	B1	National Forest Area	10,000 hectares	+
	B2	Number of Days with Excellent Air Quality in Major Cities	Day	+
Economic Level	C1	Regional Gross Domestic Product	100 million yuan	+
	C2	Business Income of High-tech Industry	10,000 yuan	+

Firstly, from the perspective of low-carbon development, it is characterized by two-way representation of industrial wastewater discharge intensity (A1) and comprehensive utilization rate of solid waste (A2). The former reflects the environmental pressure of economic growth, and the

latter reflects the efficiency of resource recycling, which together depict the characteristics of low-carbon transition.

Secondly, from the perspective of ecological benefit, forest area (B1) and urban air quality (B2) are selected as core indicators. The former directly measures the stock of ecological resources, and the latter indirectly reflects the effectiveness of environmental governance, highlighting the ecological dividends of green development[6].

Thirdly, from the perspective of economic level, regional gross domestic product (C1) is used to characterize economic scale, and high-tech industry income (C2) is used to measure structural upgrading. The combination of the two reveals the growth quality of green economy[7-8].

2.2. Evaluation Index System of New Quality Productivity

By analyzing the emerging concept of new quality productivity, this paper selects the three core elements of new quality productivity, namely the qualitative changes of laborers, objects of labor, and means of labor, and determines the second-level measurement indicators. The specific evaluation system is shown in Table 2:

Table 2 Evaluation Index System of New Quality Productivity

First-level Indicator	Serial Number	Second-level Indicator	Unit	Attribute
Laborers	A1	Enterprise Industrial Innovation Funds	10,000 yuan	+
	A2	Full-time Equivalent of Enterprise R&D Personnel	Hour	+
Objects of Labor	B1	Software Business Income	Person	+
	B2	E-commerce Sales Volume	10,000 yuan	+
Means of Labor	C1	Number of Authorized Patents by Region	Piece	+
	C2	Optical Cable Line Length/Regional Area	Meter	+

Firstly, in the theoretical system of new quality productivity, the individual dimension of laborers is mainly reflected in three aspects: efficiency, skills, and theory. Innovation funds (A1) and full-time equivalent of enterprise R&D personnel (A2) reflect the resource investment of enterprises in technological innovation, which are the core elements driving efficiency improvement.

Secondly, the objects of labor in the theory of new quality productivity are mainly reflected in new-quality industries and other aspects. Software business (B1) and e-commerce (B2) focus on the scale of emerging industries, representing the expansion of productivity in the field of digital economy.

Thirdly, the development of the theory of new quality productivity relies on the continuous accumulation of means of labor, which not only includes substantive means of production acting on the objects of labor, but also includes non-substantive elements that realize the transmission of laborers' creativity to the effectiveness of the objects of labor. The number of authorized patents (C1) reflects technological accumulation, and optical cable density (C2) measures the level of digital infrastructure. The two together constitute the material foundation of the innovation ecosystem[9-10].

3. Current Situation and Regional Differences of Green Economy Development in Provincial-Level Administrative Regions Nationwide

3.1. Overall Development Level of National Green Economy

China's green economy shows a steady growth trend on the whole. Since the proposal of the "Dual Carbon" goal, as shown in Table 3, the national green economy index has increased from 0.281 in 2015 to 0.302 in 2022, with an average annual growth rate of 0.8%. This trend indicates that the deepening of the concept of green development and policy-driven have effectively promoted the coordinated development of economy and environment, and the practical path of "lucid waters and lush mountains are invaluable assets" has gradually become clear.

Table 3 Green Economy Index of Provincial-Level Administrative Regions Nationwide from 2015 to 2022

Province/Region	2015	2016	2017	2018	2019	2020	2021	2022	Average Value	Ranking
Zhejiang	0.7825	0.7763	0.7584	0.7580	0.7535	0.7466	0.7460	0.7404	0.7577	1
Jiangsu	0.7579	0.7535	0.7466	0.7460	0.7404	-	-	-	0.7474	2
Shandong	0.6090	0.5354	0.5238	0.5361	0.5373	0.5327	0.5519	0.5602	0.5483	3
Beijing	0.4368	0.4075	0.4084	0.3568	0.3691	0.3737	0.3853	0.3838	0.3902	4
Inner Mongolia	0.3839	0.3700	0.3681	0.3661	0.3746	0.3789	0.3860	0.4008	0.3786	5
Sichuan	0.3493	0.2997	0.3452	0.3445	0.3564	0.3725	0.3779	0.3969	0.3553	6
Yunnan	0.3355	0.3034	0.3040	0.3198	0.3441	0.3583	0.3581	0.3751	0.3373	7
Heilongjiang	0.3181	0.2848	0.2844	0.3092	0.3056	0.3214	0.3173	0.3103	0.3065	8
Hubei	0.3127	0.3003	0.3183	0.3290	0.3145	0.3167	0.3160	0.3284	0.3161	9
Henan	0.3373	0.4206	0.3999	0.2703	0.2537	0.2557	0.2586	0.2570	0.3067	10
Fujian	0.2772	0.2904	0.2924	0.3223	0.2839	-	-	-	0.2932	11
Guizhou	0.2871	0.3117	0.2894	0.2458	0.2643	0.2754	0.2681	0.2886	0.2790	12
Guangxi	0.2692	0.2486	0.2481	0.2658	0.2855	0.2978	0.2956	0.3188	0.2787	13
Jiangxi	0.2415	0.2403	0.2328	0.2226	0.2435	0.2449	0.2640	0.2769	0.2458	14
Hebei	0.2218	0.1930	0.2274	0.2584	0.2581	0.2521	0.2600	0.2638	0.2418	15
Tianjin	0.2078	0.2967	0.2642	0.1890	0.1641	0.1719	0.1692	0.1629	0.2032	16
Gansu	0.1399	0.1121	0.1248	0.1269	0.1528	0.1854	0.1628	0.1722	0.1471	17

Shanxi	0.163 5	0.162 0	0.146 9	0.132 4	0.171 1	0.183 2	0.176 1	0.200 0	0.1669	18
Hainan	0.181 2	0.201 4	0.159 0	0.159 9	0.186 3	0.195 4	0.189 4	0.216 6	0.1862	19
Qinghai	0.105 5	0.079 5	0.090 1	0.112 4	0.126 3	0.165 7	0.129 6	0.150 7	0.1200	20

3.2. Characteristics of Regional Differences in Green Economy

China's green economy development shows significant gradient difference characteristics. The eastern, central, and western regions form distinct contrasts in terms of development stage, dynamic mechanism, and restrictive factors (see Figure 1).

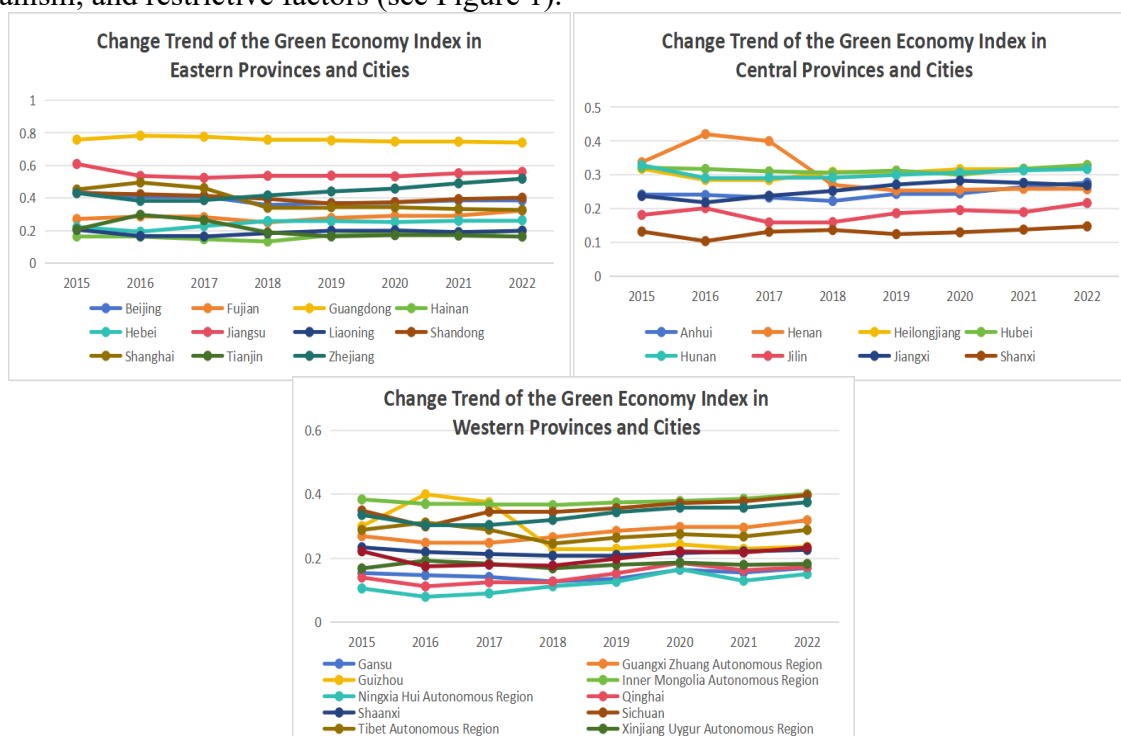


Figure 1 Trend of Green Economy Index in Eastern, Central and Western China

3.2.1 Characteristics of Eastern Region

The leading advantage of China's eastern region in green economy development is concentrated in the three-dimensional coordination of economic foundation, technological innovation, and institutional efficiency. From the perspective of industrial structure evolution, relying on a modern industrial system with the tertiary industry accounting for over 55%, this region promotes the formation of scale effects in high-value-added industries such as digital economy and biomedicine, effectively achieving the dynamic balance between economic growth and ecological protection. This industrial structure upgrading not only significantly reduces energy consumption per unit output value, but also constructs a sustainable development paradigm with promotion value. At the technical empowerment level, the full-industry chain zero-carbon transformation represented by the photovoltaic industry is typical. Through full-process technological innovation covering silicon purification to module recycling, the eastern region has formed a two-way promotion mechanism of technological R&D and industrial transformation in the field of clean energy. This collaborative innovation model provides a practical sample for breaking the dual dilemma of environmental protection and economic growth. The innovative design of the policy system highlights the multiplier effect of institutional supply. This institutional innovation not only activates the endogenous motivation of enterprises' green transformation, but also constructs a new pattern of environmental governance through a multi-subject coordination mechanism. The dynamic coupling of the three-

dimensional system jointly shapes the systematic advantage of green development in the eastern region.

3.2.2 Characteristics of Central Region

The central region is facing a "double squeeze" dilemma in the green economic transformation. On the one hand, as the main undertaking area of industrial transfer from the east, the large-scale transfer of manufacturing industry has led to a sharp increase in resource and environmental pressure. In 2022, the industrial water use intensity of the six central provinces was 18% higher than the national average, and the environmental carrying space continued to be compressed. On the other hand, the transformation process of the traditional resource-dependent economy is slow. Provinces represented by Shanxi are still trapped in the "resource curse", with the output value of the coal industry accounting for more than 20% for a long time, and the investment intensity in clean energy is only 1/3 of that in eastern provinces. This structural contradiction makes the green economy index of the central region generally hover between 0.25-0.4, becoming a "depression" of national green development.

3.2.3 Characteristics of Western Region

The western region presents a unique pattern of "coexistence of potential release and overall lag" (see Table 3). Provinces such as Inner Mongolia and Sichuan rely on abundant environmental carrying capacity and ecological compensation policy dividends, and their green economy index has exceeded the national average. Among them, Sichuan Province has achieved an average annual growth of 37% in the scale of forest carbon sink trading by building a national ecological economic pilot zone. However, on the whole, the western region is still limited by three major bottlenecks: first, weak technological innovation capacity, with R&D investment intensity only 42% of that in the eastern region; second, insufficient infrastructure supporting, with 5G base station density per 10,000 square kilometers 62% lower than that in the eastern region; third, lack of market-oriented mechanisms, with carbon trading platform coverage less than 30%. It is worth noting that the "late-development advantage" formed by low development intensity has reserved strategic buffer space for the west. If breakthroughs can be made in the construction of new energy bases and the realization mechanism of ecological product value, it is expected to build a differentiated green development path.

4. Spatial Differentiation and Driving Factors of New Quality Productivity Nationwide

4.1. National Development Pattern of New Quality Productivity

The new quality productivity index shows a "high in the east and low in the west" distribution with significant regional differences (see Table 4). Eastern provinces (such as Guangdong 0.7846, Jiangsu 0.6747) have maintained a leading position by virtue of high R&D investment (R&D ratio over 3%), digital infrastructure density (optical cable density), and innovation ecosystem advantages. Among the central and western regions, transportation hub provinces such as Henan and Anhui have achieved catch-up by undertaking technological diffusion, while traditional industrial areas such as Shanxi and Jilin are restricted by path dependence.

Based on the measurement results of the national new quality productivity development index, the study found that: first, the average and median values of the new quality productivity development index nationwide and in various regions showed a continuous upward trend during the observation period, indicating that China's scientific and technological innovation capacity has been significantly improved overall. Second, the phenomenon that the national average has been higher than the median for a long time reveals the imbalance of development among regions, that is, a few provinces and cities with high indexes have raised the overall level, while most regions are still at a relatively low

level. This feature highlights the pattern of "leading by the top" and "catching up by the long tail" in the development of China's new quality productivity.

Table 4 New Quality Productivity Index of Provincial-Level Administrative Regions Nationwide from 2015 to 2022

Province/Region	2015	2016	2017	2018	2019	2020	2021	2022	Average Value	Ranking
Guangdong	0.7366	0.7605	0.7873	0.8030	0.8050	0.7984	0.7903	0.7957	0.7846	1
Jiangsu	0.7439	0.7120	0.6799	0.6495	0.6531	0.6689	0.6325	0.6535	0.6742	2
Beijing	0.4609	0.4634	0.4780	0.4513	0.4833	0.4972	0.4981	0.5018	0.4793	3
Shandong	0.4900	0.5080	0.4911	0.4394	0.3836	0.3894	0.4274	0.4713	0.4500	4
Shanghai	0.5026	0.5044	0.4499	0.4125	0.4287	0.4202	0.4207	0.4276	0.4458	5
Zhejiang	0.4761	0.4609	0.4292	0.4225	0.4459	0.4349	0.4288	0.4224	0.4401	6
Yunnan	0.2214	0.2132	0.2125	0.2206	0.2335	0.2189	0.1945	0.2151	0.2162	7
Fujian	0.2193	0.2209	0.2123	0.2129	0.2085	0.1876	0.1941	0.1899	0.2057	8
Sichuan	0.2055	0.1989	0.1980	0.1917	0.1971	0.1884	0.1746	0.1789	0.1916	9
Hubei	0.1717	0.1789	0.1783	0.1682	0.1760	0.1638	0.1718	0.1796	0.1735	10
Henan	0.1885	0.1912	0.1781	0.1672	0.1639	0.1616	0.1650	0.1614	0.1721	11
Anhui	0.1636	0.1681	0.1629	0.1612	0.1692	0.1725	0.1812	0.1778	0.1696	12
Tianjin	0.1899	0.1775	0.1440	0.1361	0.1530	0.1520	0.1382	0.1332	0.1530	13
Hunan	0.1408	0.1382	0.1443	0.1366	0.1386	0.1453	0.1533	0.1575	0.1443	14
Liaoning	0.2408	0.1511	0.1420	0.1170	0.1197	0.1140	0.1043	0.1064	0.1373	15
Chongqing	0.1183	0.1374	0.1283	0.1215	0.1217	0.1257	0.1364	0.1578	0.1310	16
Hebei	0.1199	0.1253	0.1205	0.1083	0.1113	0.1201	0.1156	0.1188	0.1175	17
Shaanxi	0.1184	0.1260	0.1134	0.1134	0.1367	0.1163	0.1118	0.0911	0.1159	18
Jiangxi	0.0789	0.0862	0.0913	0.0978	0.1017	0.1082	0.1056	0.0972	0.0966	19
Shanxi	0.0524	0.0497	0.0505	0.0543	0.0502	0.0514	0.0575	0.0625	0.0536	20
Guangxi	0.0134	0.0436	0.0392	0.0370	0.0161	0.0513	0.0550	0.0579	0.0387	21

Guizhou	0.044 8	0.047 5	0.041 6	0.041 3	0.011 4	0.012 6	0.041 2	0.019 6	0.0337	22
Inner Mongolia	0.050 3	0.051 6	0.012 1	0.033 8	0.039 2	0.010 7	0.039 2	0.042 6	0.0322	23
Jilin	0.019 9	0.047 9	0.012 8	0.039 6	0.028 7	0.028 6	0.027 5	0.026 0	0.0284	24
Hainan	0.031 6	0.032 9	0.031 0	0.031 2	0.032 2	0.032 3	0.034 7	0.034 7	0.0326	25
Heilongjiang	0.049 5	0.041 9	0.038 4	0.023 8	0.024 0	0.024 1	0.024 2	0.024 8	0.0317	26
Ningxia	0.016 2	0.018 6	0.019 3	0.018 7	0.018 5	0.019 2	0.020 6	0.020 3	0.0189	27
Gansu	0.022 0	0.021 5	0.019 3	0.017 5	0.017 0	0.016 8	0.018 0	0.018 3	0.0188	28
Xinjiang	0.024 1	0.016 1	0.016 7	0.016 2	0.013 0	0.012 6	0.014 7	0.018 0	0.0164	29
Qinghai	0.014 8	0.008 7	0.002 8	0.002 3	0.002 9	0.003 0	0.006 0	0.005 7	0.0058	30
Tibet	0.003 4	0.001 6	0.002 9	0.003 5	0.003 1	0.001 9	0.001 9	0.001 3	0.0028	31

4.2. Analysis of Regional Differentiation Characteristics of New Quality Productivity Development in China

4.2.1 Overall Development Characteristics

The regional differences of new quality productivity in China present a significant three-level gradient structure: the eastern region leads, the central region follows, and the western region lags behind. Specifically, the eastern region has maintained a leading position in the innovation ecosystem of "technology-market-facilities". Its GDP accounts for nearly half of the country, high-value-added industries (information technology, biomedicine, new energy) are highly concentrated, and the R&D investment intensity (R&D ratio over 3%) forms a doubling advantage compared with the central and western regions (about 1.5%). In the dimension of digital economy, the absolute advantages of the eastern region in key indicators such as software service penetration rate, e-commerce scale, and digital infrastructure density (optical cable coverage rate of 98.6%) provide core momentum for the continuous growth of its new quality productivity (see Figure 2).



Figure 2 Trend of New Quality Productivity Index in Eastern, Central and Western China

4.2.2 Regional Characteristics and Driving Mechanisms

At the provincial level, as shown in Table 4, Guangdong Province ranks first with an index value of 0.7846, and its manufacturing foundation, agglomeration of scientific and technological innovation resources, and first-mover advantage in digital economy form a resonance effect. Jiangsu Province (0.6747) ranks in the second echelon relying on a complete industrial chain supporting and industry-university-research collaborative innovation mechanism. Beijing, Shandong, Shanghai, and Zhejiang have all exceeded 0.4, forming the eastern innovation core. The central and western regions show a differentiated development trend: Henan Province (0.31) has achieved corner overtaking through electronic information industry clusters, central hub provinces such as Anhui, Hubei, Hunan, and Jiangxi are close to the eastern average, while traditional industrial areas such as Shanxi, Heilongjiang, and Jilin are obviously lagging behind due to industrial structure rigidity. The western region takes Sichuan and Chongqing (0.28) as the growth pole, but Gansu, Ningxia, Inner Mongolia and other places are still in the catch-up stage due to infrastructure and innovation factor constraints.

5. Conclusions

This study systematically measured the green economy and new-type productive forces across provincial-level administrative units nationwide by constructing a multidimensional indicator system and applying the Entropy Weight-TOPSIS model, revealing key characteristics and spatial differentiation patterns in China's regional development.

Evaluation Framework and Measurement Methodology: A synergistic evaluation system was established, encompassing green economy (three dimensions: low-carbon development, ecological benefits, economic level) and new-quality productivity (three dimensions: labor force, labor objects, labor resources). The Entropy Weight-TOPSIS measurement method was adopted to effectively mitigate subjectivity in manual weighting and provide a professional, rational solution for multi-indicator problems.

Regional Differentiation of Green Economy: During the observation period (2015 - 2022), the national green economy index demonstrated steady growth, rising from 0.281 to 0.302. However, development patterns exhibited a pronounced gradient difference characterized by higher in the east, lower in the west. The eastern region leveraged its advanced industrial structure (where the tertiary

sector accounts for over 55%), technological innovation capabilities, and institutional efficiency to establish systemic advantages, thereby constructing a sustainable development paradigm with replicable value. The central region faces a double squeeze dilemma: environmental pressures from industrial relocation and sluggish transformation of traditional resource-based economies, making it a low-lying area for national green development. While the western region lags overall, it possesses the late-mover advantage of potential release and strategic buffer space based on its ecological carrying capacity.

Spatial Differentiation of New Quality Productivity: The new quality productivity index also exhibits an east-high, west-low distribution with pronounced regional disparities. Eastern provinces (e.g., Guangdong 0.7846, Jiangsu 0.6747) maintain leading positions through high R&D intensity (R&D share exceeding 3%), digital infrastructure density (fiber optic density), and innovation ecosystem advantages. The persistent gap between the national average and median reveals regional development imbalances, highlighting a coexisting pattern of front-runner leadership and long-tail catch-up. Central regions exhibit differentiated development trajectories, with some hub provinces catching up through technology diffusion, while traditional industrial zones lag due to path-dependent constraints. These findings provide quantitative support for establishing a coordinated regional development framework: Eastern technological leadership – Central structural transformation – Western ecological compensation.

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