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Measurement and Evaluation of Regional Competitiveness of the Nine Provinces in the Yellow River Basin Based on Entropy Weight-TOPSIS Method

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Abstract: The Yellow River Basin occupies an important strategic position in China's ecological security and economic development pattern. Scientifically measuring the regional competitiveness of the nine provinces in the basin and revealing its spatial differentiation characteristics are of great practical significance for promoting ecological protection and high-quality development of the Yellow River Basin. Based on the new development philosophy, this paper constructs a regional competitiveness evaluation system covering 22 specific indicators from seven dimensions: economic growth, industrial structure, cultural industry, green ecology, opening-up, infrastructure, and innovation capacity. The Entropy Weight-TOPSIS method is adopted to comprehensively measure and systematically analyze the competitiveness level of the nine provinces in the Yellow River Basin. The results show that the regional competitiveness of the nine provinces presents significant spatial disequilibrium, with a gradient distribution pattern of "strong in the east, weak in the west, and gradually declining from east to west". Shandong Province ranks first in comprehensive competitiveness, followed by Sichuan and Henan, while Qinghai and Gansu are at the bottom. From the dimensional perspective, obvious differences exist in economic growth, industrial structure and opening-up; midstream provinces perform better in green ecology; innovation capacity has become the core factor leading to competitiveness differentiation, and cultural industry is a common shortcoming across the basin. Overall, the competitiveness gap in the basin results from the combined effects of economic foundation, industrial structure, innovation factors and ecological background. Finally, policy implications are put forward from strengthening leading drive, implementing targeted policies, and focusing on innovation and green development, so as to provide a reference for synergistically improving the regional competitiveness of the nine provinces and realizing coordinated regional development in the Yellow River Basin.

Keywords: Yellow River Basin; Regional Competitiveness; Entropy Weight-TOPSIS Method; Spatial Differentiation; High-Quality Development

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1. Introduction

The Yellow River Basin plays a vital role in China's economic and social development and ecological security [1]. The provinces it flows through are not only important components of high-quality economic development in the basin, but also a solid foundation for enhancing basin competitiveness, which is crucial for stabilizing the northern economy and promoting

economic construction with the domestic circulation as the mainstay [2]. Since the 18th National Congress of the Communist Party of China, the development and protection of the Yellow River Basin have received unprecedented attention, which has greatly boosted the regional competitiveness of the nine provinces in the basin. By 2021, the total population of the nine provinces in the Yellow River Basin reached 420 million, accounting for one-third of the national total, and their regional GDP amounted to nearly 30 trillion yuan, making up one-quarter of the national total. Although the nine provinces have made remarkable progress in development, there are still heterogeneities among provinces in geographical location, natural environment, resource endowment, talent scale, industrial policies, opening-up level and other aspects, leading to obvious gaps in regional competitiveness. To improve the regional competitiveness of each province in a more balanced, sustainable and stable manner, it is necessary to scientifically measure the regional competitiveness of the nine provinces, form a situation of complementary advantages and collaborative interaction among them, and thus promote coordinated regional development. This is of great significance for facilitating the implementation of the strategy for ecological protection and high-quality development of the Yellow River Basin.

Regional competition refers to competitive activities among multiple regions based on resource factors. Well-known academic discussions on international competitiveness include the studies conducted by the World Economic Forum (WEF), the International Institute for Management Development (IMD) and Michael Porter on international competitiveness. In 1989, the former State Commission for Restructuring the Economic System began to cooperate with WEF-IMD to study international competitiveness, and since then Chinese scholars have launched research on regional competitiveness. At present, domestic scholars mainly study regional competitiveness by constructing evaluation index systems, but most studies focus on the national, inter-provincial and urban levels. For example, Huang Guoyan, Liu Jianghui, et al. constructed an evaluation index system for global urban network competitiveness and compared the competitiveness of major cities at home and abroad [3]; Li Lin and Cao Can established an evaluation system for regional economic development in Hunan Province from six aspects: effectiveness, stability, innovation, coordination, greenness and sharing [4]; Dong Suocheng, Li Zehong, et al. constructed an urban competitiveness evaluation index system for state-level new areas from the perspectives of national development strategy, economic development and location conditions [5]; Zhang Chao, Li Changbiao, et al. built an evaluation system for regional coordinated development from five dimensions: economic development, public services, infrastructure, people's livelihood and ecological environment [6]; Wu Shaohua and Li Yujia constructed an urban competitiveness evaluation index system for western China from economic strength, infrastructure, social security and other aspects [7]; Xiao Feng, Wang Peng, et al. established a provincial competitiveness evaluation index system for the Yangtze River Economic Belt from economic growth and industrial structure [8].

Through literature review, it can be seen that the evaluation scope of regional competitiveness covers the national, inter-provincial and urban levels, but there are few studies taking the Yellow River Basin as the research object. The research methods mainly rely on constructing index evaluation systems to analyze regional competitiveness, and the research contents mostly focus on high-quality development [9] and ecological protection [10], lacking research on the regional competitiveness of provinces in the Yellow River Basin. Therefore, this paper takes the nine provinces in the Yellow River Basin as the research object, measures and analyzes their regional competitiveness, and explores the current development status and existing problems, so as to provide theoretical support and practical reference for the high-quality development of the Yellow River Basin.

2. Construction of the Evaluation Index System for Regional Competitiveness

2.1 Study Area

The Yellow River Basin crosses four major geomorphic units from west to east: the Qinghai-Tibet Plateau, the Inner Mongolia Plateau, the Loess Plateau, and the Huang-Huai-Hai Plain. It flows through nine provincial-level regions: Qinghai, Sichuan, Gansu, Ningxia, Inner Mongolia, Shaanxi, Shanxi, Henan, and Shandong. With a vast basin area and a large population, the Yellow River Basin serves as a critical ecological barrier and economic zone in China. Meanwhile, the basin is characterized by a fragile ecological environment and a severe water resource supply situation. The ecological protection and high-quality development of the Yellow River Basin has become another national strategy following the Yangtze

River Economic Belt, the Yangtze River Delta Integration, the Beijing-Tianjin-Hebei Coordinated Development, and the Guangdong-Hong Kong-Macao Greater Bay Area.

2.2 Construction of the Evaluation Index System

The regional competitiveness evaluation index system provides a comprehensive assessment of economy, society, ecology, industry, culture, and other dimensions. In establishing the index system for the nine provinces in the Yellow River Basin, this paper adheres to the principles of hierarchy, operability, and comprehensiveness. With reference to relevant studies by Xiao Feng, Wang Peng et al.[11] and Ren Baoping, Gong Yuhao et al.[12], and in line with the new development philosophy featuring innovation, coordination, green development, opening-up, and sharing, this study takes full account of the economic development and cultural industry performance of each province. Seven first-level indicators are determined: economic growth, industrial structure, cultural industry, green ecology, opening-up, infrastructure, and innovation capacity. On this basis, 22 second-level indicators are selected, including 21 positive indicators and 1 negative indicator. The measurement index system of regional competitiveness of the nine provinces in the Yellow River Basin is shown in Table 1.

Table 1 Index System for Measuring Regional Competitiveness of the Nine Provinces in the Yellow River Basin

First-level Indicators	Second-level Indicators	Attribute	Weight
Economic Growth (Foundation)	Gross Regional Product (100 million yuan)	Positive	0.0463
	Fixed Asset Investment (100 million yuan)	Positive	0.0477
	Local Fiscal Revenue (100 million yuan)	Positive	0.0483
Industrial Structure (Guarantee)	Added Value of Secondary Industry (100 million yuan)	Positive	0.0353
	Added Value of Tertiary Industry (100 million yuan)	Positive	0.0446
	Total Electricity Consumption (100 million kWh)	Positive	0.0477
Cultural Industry (Performance)	Number of Cultural and Related Industries Units	Positive	0.0134
	Employees in Cultural and Related Industries	Positive	0.0403
	Operating Income of Cultural Industries (10,000 yuan)	Positive	0.036
Green Ecology (Requirement)	Forest Coverage Rate (%)	Positive	0.0514
	Sulfur Dioxide Emissions (10,000 tons)	Negative	0.0431
	Green Coverage Rate in Built-up Areas (%)	Positive	0.0555
Opening-up (Approach)	Foreign Investment (100 million yuan)	Positive	0.053
	Total Imports and Exports of Goods (10,000 yuan)	Positive	0.0291
	International Tourism Income (million USD)	Positive	0.0371
Infrastructure (Content)	Number of Urban Basic Medical Insurance Participants (10,000 persons)	Positive	0.0414
	Number of Doctors per 1,000 Persons	Positive	0.0455
	Number of Public Libraries	Positive	0.0451
	Per Capita Urban Road Area (sq.m.)	Positive	0.0538
Innovation Capacity (Momentum)	R&D Expenditure (100 million yuan)	Positive	0.0481
	Patent Applications	Positive	0.0419
	College Students per 100,000 Persons	Positive	0.0398

2.2.1 Economic Growth Index System

Economic growth is the solid foundation for improving regional competitiveness, reflecting the productivity and economic momentum of provinces, as well as a prerequisite for modernization and sustainable development in the Yellow River Basin. Indicators including gross regional product, fixed asset investment, and local fiscal revenue are selected to measure economic growth.

2.2.2 Industrial Structure Index System

Industrial structure is an important guarantee for enhancing regional competitiveness. A reasonable industrial structure helps form a sound industrial cycle and rational division of labor, narrowing gaps among upper, middle, and lower reaches. Given the long-term dominance of heavy and chemical industries in the Yellow River Basin, indicators such as added value of secondary and tertiary industries and total electricity consumption are used to analyze the rationalization level of industrial structure[13].

2.2.3 Cultural Industry Index System

As an important birthplace of traditional Chinese culture, the Yellow River Basin boasts unique advantages for cultural industry development. Three indicators—number of cultural enterprises, employees, and operating income—are adopted to measure input and output performance of the cultural industry.

2.2.4 Green Ecology Index System

Green development is a strategic requirement for the Yellow River Basin. Given its fragile ecology and severe pollution, forest coverage rate, sulfur dioxide emissions, and green coverage rate in built-up areas are selected to reflect ecological protection and environmental governance.

2.2.5 Opening-up Index System

Opening-up is an effective way to boost regional competitiveness. Foreign investment, total imports and exports, and international tourism income are used to measure the degree of opening-up and external connectivity.

2.2.6 Infrastructure Index System

Infrastructure supports high-quality development and regional connectivity. Indicators including medical insurance coverage, doctors per capita, public libraries, and per capita road area are selected to reflect infrastructure and public service levels.

2.2.7 Innovation Capacity Index System

Innovation is the long-term driving force for competitiveness. R&D expenditure, patent applications, and college students per 100,000 persons reflect innovation input, output, and talent reserve.

2.3 Data Sources and Research Methods

Statistical data are mainly obtained from China Statistical Yearbook (2023), China Fixed Investment Statistical Yearbook, and China Fixed Investment Statistical Annual Report. Missing 2023 data are supplemented by 2022 provincial data.

The Entropy Weight-TOPSIS method is adopted for comprehensive evaluation. This method combines entropy weight (for objective weighting) and TOPSIS (for ranking by relative closeness to the ideal solution). The comprehensive score C is calculated; a value closer to 1 indicates stronger competitiveness.

3. Analysis of Evaluation Results of Regional Competitiveness

3.1 Model Results

Indicator weights are calculated using the entropy weight method, as shown in Table 2.

Table 2 Weight Results Calculated by Entropy Weight Method

Secondary Indicators	Entropy Value e	Information Utility Value d	Weight Coefficient w
Gross Regional Product (100 million yuan)	3.884992	-2.88499169	0.0463471
Fixed Asset Investment (100 million yuan)	3.968548	-2.96854811	0.0476894
Local Fiscal Revenue (100 million yuan)	4.008212	-3.00821175	0.0483266
Added Value of Secondary Industry (100 million yuan)	3.198202	-2.19820227	0.0353139

Secondary Indicators	Entropy Value e	Information Utility Value d	Weight Coefficient w
Added Value of Tertiary Industry (100 million yuan)	3.775001	-2.77500068	0.0445801
Total Social Electricity Consumption (100 million kWh)	3.9677	-2.96769969	0.0476758
Number of Cultural and Related Industry Units (units)	1.83363	-0.83363035	0.0133922
Employees in Cultural and Related Industries (persons)	3.506054	-2.50605403	0.0402595
Operating Income of Cultural and Related Industries (10,000 yuan)	3.243658	-2.24365783	0.0360442
Forest Coverage Rate (%)	4.196501	-3.19650096	0.0513515
Per Capita Green Space Area (square meters)	3.684057	-2.68405653	0.0431191
Sulfur Dioxide Emissions (10,000 tons)	4.454085	-3.45408503	0.0554896
Green Coverage Rate in Built-up Areas (%)	4.298366	-3.29836589	0.0529879
Foreign Investment Amount (100 million yuan)	2.813399	-1.81339873	0.0291321
Total Import and Export Volume of Foreign Trade Goods (10,000 yuan)	3.308228	-2.30822849	0.0370815
International Tourism Income (million USD)	3.575699	-2.5756987	0.0413784
Number of Urban Basic Medical Insurance Participants (10,000 persons)	3.830542	-2.83054205	0.0454724
Number of Doctors per 1,000 Persons (persons)	3.80629	-2.80628981	0.0450828
Number of Public Libraries (units)	4.346279	-3.34627943	0.0537577
Per Capita Urban Road Area (square meters)	3.997122	-2.9971217	0.0481485
R&D Expenditure (100 million yuan)	3.606185	-2.60618486	0.0418681
Number of Patent Applications (pieces)	3.478879	-2.47887915	0.039823
Number of College Students per 100,000 Persons (persons)	4.465859	-3.465859	0.0556787

The positive ideal solution (R^+) and negative ideal solution (R^-) are obtained, and Euclidean distances D^+ and D^- are calculated (Table 3). The comprehensive closeness coefficient C is then derived and ranked (Table 4).

Table 3 Positive and Negative Ideal Solutions

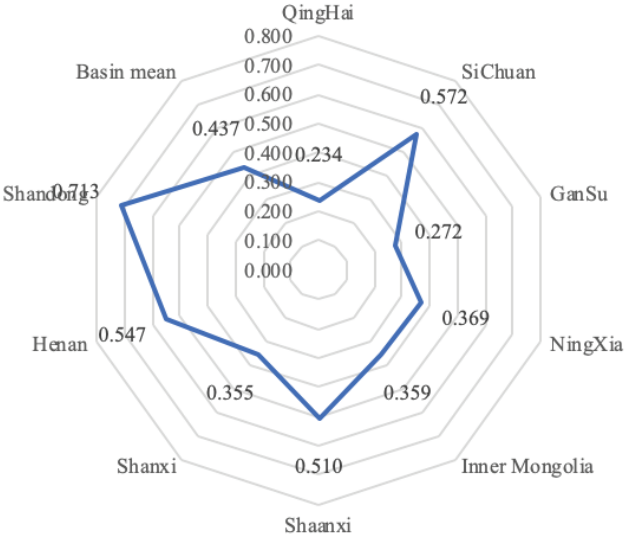
Secondary Indicators	Positive Ideal Solution R+	Negative Ideal Solution R−
Gross Regional Product (100 million yuan)	0.046393	0.000046
Fixed Asset Investment (100 million yuan)	0.047737	0.000048
Local Fiscal Revenue (100 million yuan)	0.048375	0.000048
Added Value of Secondary Industry (100 million yuan)	0.035349	0.000035
Added Value of Tertiary Industry (100 million yuan)	0.044625	0.000045
Total Social Electricity Consumption (100 million kWh)	0.047723	0.000048
Number of Cultural and Related Industry Units (units)	0.013406	0.000013
Employees in Cultural and Related Industries (persons)	0.0403	0.00004
Operating Income of Cultural and Related Industries (10,000 yuan)	0.03608	0.000036
Forest Coverage Rate (%)	0.051403	0.000051
Per Capita Green Space Area (square meters)	0.043162	0.000043
Sulfur Dioxide Emissions (10,000 tons)	0.055545	0.000055
Green Coverage Rate in Built-up Areas (%)	0.053041	0.000053

Secondary Indicators	Positive Ideal Solution R+	Negative Ideal Solution R−
Foreign Investment Amount (100 million yuan)	0.029161	0.000029
Total Import and Export Volume of Foreign Trade Goods (10,000 yuan)	0.037119	0.000037
International Tourism Income (million USD)	0.04142	0.000041
Number of Urban Basic Medical Insurance Participants (10,000 persons)	0.045518	0.000045
Number of Doctors per 1,000 Persons (persons)	0.045128	0.000045
Number of Public Libraries (units)	0.053811	0.000054
Per Capita Urban Road Area (square meters)	0.048197	0.000048
R&D Expenditure (100 million yuan)	0.04191	0.000042
Number of Patent Applications (pieces)	0.039863	0.00004
Number of College Students per 100,000 Persons (persons)	0.055734	0.000056

Table 4 Relative Closeness C and Ranking of Regional Competitiveness of Provinces in the Yellow River Basin

Province	Relative Closeness C	Ranking
Qinghai	0.234	9
Sichuan	0.572	2
Gansu	0.272	8
Ningxia	0.369	5
Inner Mongolia	0.359	6
Shaanxi	0.51	4
Shanxi	0.355	7
Henan	0.547	3
Shandong	0.713	1

Figure 1 Relative Closeness C of Regional Competitiveness Level of Provinces in the Yellow River Basin



3.2 Analysis of the Evaluation and Measurement Results of Regional Competitiveness of the Nine Provinces in the Yellow River Basin

From the measurement results in Table 4 and the comprehensive competitiveness radar chart, the regional competitiveness

of the nine provinces in the Yellow River Basin presents significant spatial disequilibrium and a stepped gradient distribution feature. The overall pattern follows the law of "gradual attenuation from east to west", which is highly consistent with the economic and geographical location, resource endowment conditions and policy implementation intensity in the basin.

In terms of comprehensive competitiveness, Shandong Province ranks first with a relative closeness value of 0.713, becoming the absolute leading engine for high-quality development in the Yellow River Basin. Its scores on all indicators far exceed the average level of the basin, showing a gap-leading advantage in the comprehensive competitiveness dimension, and it is the only first-echelon province with all-round comprehensive strength in the basin. Sichuan Province (0.572) and Henan Province (0.547), which follow closely, rank second and third respectively. As the southwest growth pole and the core of the Central Plains hinterland, they have constructed a dual-core-driven growth pattern of "east, central and west" in the Yellow River Basin. Shaanxi Province (0.510) ranks fourth by virtue of its advantages in science, education and technological innovation, and is in the transition zone from the first echelon to the second echelon.

Ningxia Hui Autonomous Region (0.369), Inner Mongolia Autonomous Region (0.359) and Shanxi Province (0.355), which rank in the middle reaches of the comprehensive competitiveness, have relatively close C values, forming a distinctive intermediate force. The provinces in this echelon generally have a resource-based industrial foundation or specific location advantages, but there are still shortcomings in the balanced allocation of comprehensive factors, facing the dual pressures of industrial transformation and ecological governance, and their competitiveness level is basically above the average level of the basin.

Qinghai Province (0.234) and Gansu Province (0.272), which rank at the end of the basin, have comprehensive competitiveness scores significantly lower than the basin average, with a huge gap from the leading provinces. In particular, despite its unique ecological background, Qinghai Province is restricted by factors such as small economic volume, backward infrastructure and lack of innovation factors, and its comprehensive competitiveness is in the weakest position in the whole basin.

On the whole, the regional competitiveness of the Yellow River Basin presents a dumbbell-shaped structure of "high concentration in the head, differentiated echelons in the waist, and overall lag in the tail". This pattern not only reflects the objective gaps in economic aggregate, public services and innovation capacity between the eastern, central and western regions, but also reveals the practical challenges in the process of coordinated development of the Yellow River Basin, such as how to narrow the gap between the east and the west through policy inclination and achieve a win-win situation between ecological protection and economic growth. The leading advantages of Shandong, Henan and Sichuan are not only reflected in economic scale, but also in the comprehensive control ability of total factor productivity; while the backwardness of upstream provinces is mainly restricted by structural obstacles such as ecological burden, weak foundation and brain drain.

To investigate the dimensional differences among the nine provinces in the Yellow River Basin, a further comparison is made on the dimensional measurement values of the nine provinces in 2022. The comparisons of regional competitiveness in each dimension are shown in Figures 2–8.

Figure 2 Economic Growth Dimension

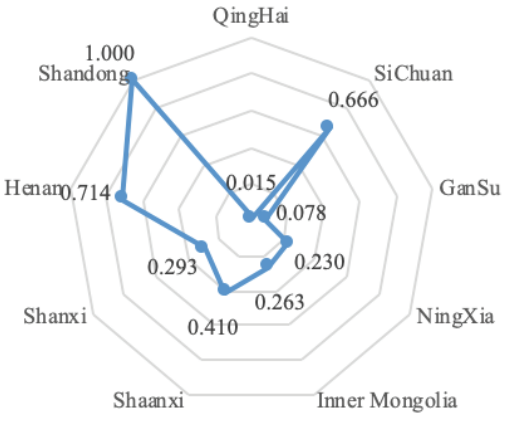


Figure 3 Industrial Structure Dimension

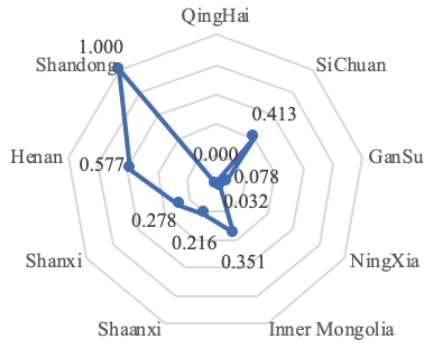


Figure 4 Cultural Industry Dimension

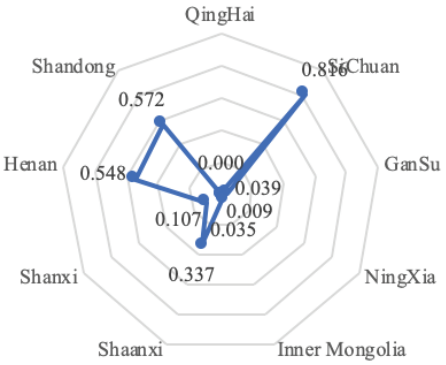


Figure 5 Green Ecology Dimension

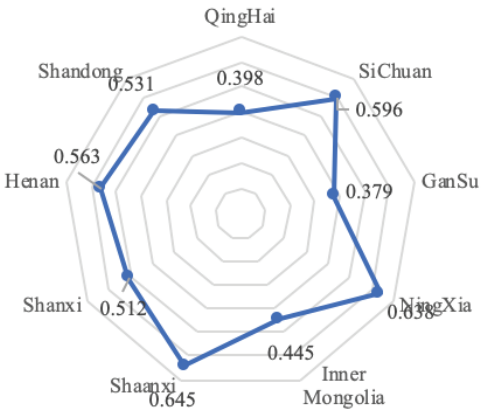


Figure 6 Opening-up Dimension

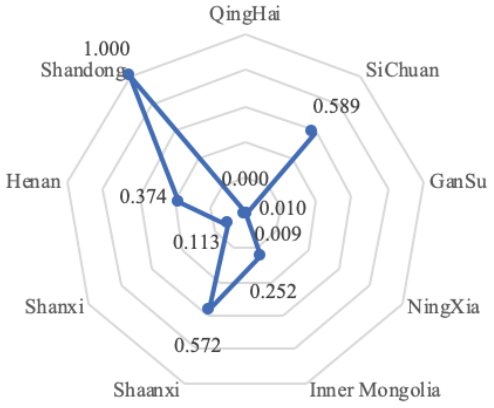


Figure 7 Infrastructure Dimension

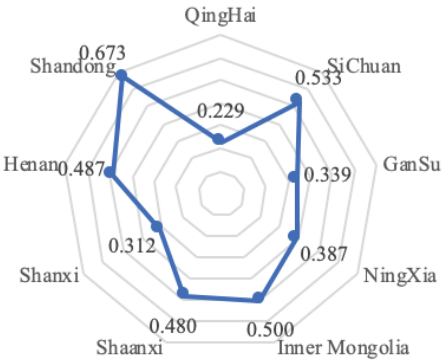
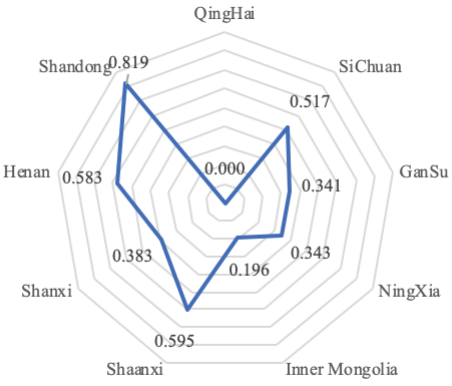


Figure 8 Innovation Capacity Dimension



3.2.1 Economic Growth Dimension

According to the evaluation results of economic growth, the nine provinces in the Yellow River Basin present an extremely significant gradient differentiation pattern. Shandong takes a leading position with a full score of 1.000, followed by Henan (0.7136) and Sichuan (0.6665), which together constitute the first echelon of economic growth in the basin. Shaanxi, Shanxi, Inner Mongolia and Ningxia are at the middle level with scores ranging from 0.2 to 0.4. Gansu and Qinghai score only 0.0783 and 0.0154 respectively, over 60 times lower than the leading provinces, placing them in an absolutely weak position. Such a differentiated pattern stems from the combined effects of location, population size, industrial structure and fiscal capacity. Shandong and Henan are located in the lower Yellow River plain with large populations and high urbanization rates, possessing inherent advantages for economic expansion. Their core indicators such as GDP, local fiscal revenue and fixed asset investment have long ranked top in the basin, making them traditional growth poles. Sichuan, relying on the strategic dividend of the Chengdu-Chongqing Economic Circle, has become a core hub of population and industry aggregation in southwest China, surpassing midstream resource-based provinces in economic scale and forming a dual-core growth pattern of the lower reaches and southwest China. In contrast, Shaanxi, Shanxi and Inner Mongolia in the middle reaches take energy and heavy chemical industries as the leading sectors, with economic growth highly dependent on resource price fluctuations. Their monotonous industrial structure leads to insufficient growth momentum and weak risk resistance. Gansu and Qinghai in the upper reaches are restricted by small economic aggregates and low fiscal self-sufficiency, with weak driving effects of fixed asset investment, falling into a vicious circle of weak economy, low investment and slow growth. This eventually forms an extreme pattern of leadership in the lower reaches and collapse in the upper reaches, which constitutes the fundamental cause of the overall imbalance of regional competitiveness in the Yellow River Basin.

3.2.2 Industrial Structure Dimension

The evaluation results of industrial structure maintain the overall trend of strong east and weak west. Shandong takes an absolute lead with a full score of 1.000, and Henan (0.577) and Sichuan (0.413) rank second and third respectively,

forming the first echelon of industrial structure optimization. Inner Mongolia, Shanxi and Shaanxi are in the middle stage of transformation with scores between 0.2 and 0.35. Gansu, Ningxia and Qinghai score less than 0.1, and Qinghai ranks last with 0.000, showing prominent shortcomings in industrial structure. Fundamentally, this difference reflects the comprehensiveness of industrial systems, the advancement of structure and the effectiveness of transformation. As one of the provinces with the most complete industrial categories in China, Shandong boasts coordinated development of secondary and tertiary industries, driven by both manufacturing and modern services, leading the basin in rationalization and advancement of industrial structure. Relying on the geographical advantage of the Central Plains Urban Agglomeration, Henan has built a complete industrial chain dominated by equipment manufacturing and food processing, with its industrial structure continuously upgraded to become a benchmark for structural optimization in the middle and lower reaches. However, as traditional energy-intensive provinces, Inner Mongolia, Shanxi and Shaanxi have long maintained a high proportion of secondary industry with a heavy and monotonous structure and lagging service industries. Despite high total social electricity consumption, most is consumed by energy-intensive industries with low added value, and slow transformation restricts the improvement of structural competitiveness. The upper reaches including Gansu, Ningxia and Qinghai are dominated by agriculture, animal husbandry and primary energy processing with weak industrial foundations. Their tertiary industries rely on traditional consumer services with insufficient support from emerging industries, resulting in weak driving effects on economic growth. The final pattern of leading head, transforming middle reaches and collapsing upper reaches confirms that industrial structure optimization is the core approach to enhancing regional competitiveness.

3.2.3 Cultural Industry Dimension

The evaluation of cultural industry shows a distinctive pattern of Sichuan standing out and the whole basin lagging behind generally. Sichuan takes a leading position with a high score of 0.816, followed by Shandong (0.572) and Henan (0.548) as the first echelon. Shaanxi and Shanxi score less than 0.4 at the middle level, while Gansu, Inner Mongolia, Ningxia and Qinghai all score below 0.04, with Qinghai ranking bottom at 0.000, nearly devoid of cultural industry competitiveness. The core cause lies in the serious mismatch between cultural resource endowment and industrial transformation capacity. As the core birthplace of Chinese civilization, the nine provinces boast abundant historical, revolutionary and intangible cultural heritage, yet "large in resources but small in industry" is a common problem across the basin. Relying on the culture-tourism integration strategy of the Chengdu-Chongqing Economic Circle, Sichuan has successfully developed world-class cultural IPs such as Sanxingdui and Jiuzhaigou, ranking first in the basin in the number of cultural enterprises, employees and business income, realizing efficient transformation from cultural resources to industrial competitiveness. Shandong and Henan have promoted large-scale development of cultural industries by virtue of population and market advantages, forming a certain industrial foundation. Nevertheless, Shaanxi and Shanxi, despite possessing top cultural resources such as Qin and Jin cultures, suffer from low industrialization, lack of nationally influential cultural IPs and leading enterprises, failing to convert resource advantages into industrial strengths. Restricted by economic scale, market capacity and talent reserve, the upper-reach provinces including Gansu, Qinghai, Ningxia and Inner Mongolia have a small number of cultural market entities and low business income with insufficient market-oriented operation. Cultural resource development mostly stays at the primary tourism stage without forming a complete industrial chain, making cultural industry a common shortcoming of competitiveness in the basin and one of the areas with the greatest potential for future improvement.

3.2.4 Green Ecology Dimension

The green ecology evaluation breaks the traditional pattern of strong east and weak west, featuring leadership in the middle reaches, follow-up in the upper reaches and mediocrity in the lower reaches. Shaanxi and Ningxia rank top with scores of 0.645 and 0.638 respectively. Sichuan, Henan, Shandong and Shanxi are at the upper-middle level with scores between 0.5 and 0.6. Inner Mongolia, Qinghai and Gansu rank downstream with scores from 0.37 to 0.45. This pattern results from ecological background, pollution control and urban greening. As core regions for ecological protection in the middle Yellow River, Shaanxi and Ningxia have continuously implemented ecological projects such as returning farmland to forest and desert control in recent years, performing well in green coverage rate of built-up areas. Meanwhile, they have strictly controlled sulfur dioxide emissions, realizing coordinated ecological protection and pollution control. Sichuan and Qinghai,

relying on the ecological advantages of the upper Yangtze and Yellow Rivers, rank high in natural ecological indicators such as forest coverage with obvious foundational strengths. As densely populated and industrialized lower-reach provinces, Shandong and Henan have achieved remarkable results in pollution reduction and urban greening despite weaker ecological backgrounds, balancing economic development and ecological protection. As traditional energy provinces, Shanxi and Inner Mongolia have gradually improved ecological competitiveness through energy restructuring and pollution control despite high sulfur dioxide emissions. Gansu, restricted by ecological fragility and economic pressure, faces great difficulties in balancing protection and governance, thus ranking low. Overall, the green ecology results confirm that "ecological priority and green development" has become a core criterion for regional competitiveness in the Yellow River Basin, where pollution reduction and ecological restoration directly determine regional ecological competitiveness.

3.2.5 Opening-up Dimension

The opening-up evaluation presents an extremely differentiated pattern of absolute leadership by Shandong, follow-up by southwest provinces and collapse in the upper reaches. Shandong takes a leading position with a full score of 1.000, followed by Sichuan (0.589) and Shaanxi (0.572), and Henan ranks fourth with 0.374. Inner Mongolia and Shanxi score less than 0.3, while Gansu, Ningxia and Qinghai score below 0.01, with Qinghai at the bottom of 0.000, showing a huge gap in opening-up levels. The core cause lies in differences in geographical conditions, opening channels and export-oriented industrial foundations. As the only coastal province in the Yellow River Basin, Shandong has world-class ports such as Qingdao and Yantai, ranking first in core indicators including foreign trade volume, foreign investment and international tourism income, serving as the leading gateway for opening-up. Sichuan and Shaanxi, relying on opening channels such as China-Europe Railway Express and international aviation hubs, have built highlands for inland opening-up with sound export-oriented industries and high opening levels. Henan, supported by Zhengzhou Airport and China-Europe Railway Express (Zhengzhou), has become an important opening node in the middle and lower reaches. However, Inner Mongolia and Shanxi, despite border-opening advantages, suffer from weak export-oriented industries and small foreign trade scales. The inland upper-reach provinces including Gansu, Qinghai and Ningxia lack sufficient opening channels and lag in export-oriented industries, with minimal foreign capital utilization, foreign trade and international tourism income, resulting in extremely low opening levels and becoming a core bottleneck restricting the improvement of regional competitiveness. Overall, the opening-up level of the Yellow River Basin is generally low with insufficient release of opening dividends, and the opening shortcomings of inland provinces are key breakthroughs for coordinated development.

3.2.6 Infrastructure Dimension

The infrastructure evaluation shows a pattern of leadership by Shandong, mediocrity of multiple provinces and weakness in the upper reaches. Shandong ranks first with a high score of 0.673. Sichuan, Inner Mongolia, Henan and Shaanxi are at the upper-middle level with scores from 0.48 to 0.54. Ningxia, Gansu and Shanxi score between 0.3 and 0.4, and Qinghai ranks last with 0.229. This pattern is jointly shaped by economic strength, population size and policy investment. As an economically strong province, Shandong boasts strong fiscal capacity, leading comprehensively in infrastructure and public service indicators such as urban basic medical insurance participants, doctors per 1,000 people, public libraries and per capita urban road area, with the strongest infrastructure support capacity in the basin. As large population and economic provinces, Sichuan and Henan invest heavily in infrastructure with complete public service systems and high infrastructure levels. Inner Mongolia and Shaanxi, supported by fiscal revenue from energy industries, have continuously improved infrastructure to a medium-upper level. Restricted by economic scale and fiscal strength, Ningxia, Gansu and Shanxi invest insufficiently in infrastructure with low equalization of public services. Qinghai, due to sparse population and complex geographical conditions, faces high costs and difficulties in infrastructure construction with low per capita infrastructure levels, thus ranking bottom. Overall, infrastructure competitiveness is highly positively correlated with regional economic strength. Infrastructure perfection directly determines regional development carrying capacity and livelihood security, and remedying infrastructure shortcomings in upper-reach provinces is crucial for narrowing regional gaps.

3.2.7 Innovation Capacity Dimension

The innovation capacity evaluation presents a pattern of leadership by Shandong, follow-up by Shaanxi, Henan and Sichuan,

and lagging in the upper reaches. Shandong takes a leading position with a high score of 0.819. Shaanxi (0.595), Henan (0.583) and Sichuan (0.517) rank second to fourth respectively, forming the first echelon of innovation capacity. Shanxi, Ningxia and Gansu are at the middle level with scores from 0.34 to 0.39. Inner Mongolia and Qinghai score less than 0.2, and Qinghai ranks last with 0.000, showing a significant innovation gap. The core cause lies in differences in scientific and educational resources, R&D investment and talent reserve. As an economically and educationally strong province, Shandong ranks first in core innovation indicators such as R&D expenditure, patent applications and college students per 100,000 people, with outstanding innovation-driven development capacity. Relying on science and education centers such as Xi'an and Chengdu, Shaanxi and Sichuan boast abundant university resources, high R&D intensity and strong patent output, becoming core growth poles for innovation in the basin. Henan, supported by population and industrial advantages, has continuously increased R&D investment with steadily improving innovation capacity. As resource-based provinces, Shanxi and Inner Mongolia suffer from insufficient R&D investment and shortage of high-end talents with lagging innovation capacity. Restricted by shortage of scientific and educational resources and serious brain drain, the upper-reach provinces including Gansu, Qinghai and Ningxia have weak ability to gather innovation factors, minimal R&D investment and patent output, nearly devoid of innovation-driven capacity, thus ranking bottom. Overall, innovation capacity is highly positively correlated with comprehensive regional competitiveness. Talent and technology have become core variables differentiating regional competitiveness in the Yellow River Basin, and innovation-driven development is the fundamental momentum for high-quality development.

4. Conclusions and Policy Recommendations

This study comprehensively measures the regional competitiveness of the nine provinces in the Yellow River Basin using the entropy weight-TOPSIS method. The results show that the regional competitiveness presents significant spatial disequilibrium and stepped gradient distribution, following the law of "strong in the east, weak in the west and gradual attenuation from east to west".

Comprehensively, Shandong ranks first in the basin with a high score of 0.713 as the only leading province with all-round advantages. Sichuan and Henan rank second and third, forming a dual-core growth pole of "southwest-central plains". Shaanxi ranks fourth. Ningxia, Inner Mongolia and Shanxi constitute the middle echelon. Qinghai and Gansu rank at the bottom with a huge competitiveness gap.

Dimensional analysis shows that economic growth, industrial structure and opening-up are traditional foundations widening the gap. Innovation capacity and green ecology have become key variables determining competitiveness differentiation, where regional gaps in scientific and educational resources and pollution control effectiveness directly decide competitiveness levels. As a common shortcoming across the basin, cultural industry reflects insufficient transformation of Yellow River cultural resources into industrial competitiveness. Overall, the competitiveness gap in the basin results from the combined effects of economic foundation, industrial structure, innovation factors and ecological background.

Based on the above conclusions, the following policy recommendations are proposed:

First, strengthen leading drive and multi-polar coordination to build a new pattern of coordinated basin development. Give full play to the radiation and driving role of Shandong as the basin leader, deepen its benchmark effect in opening-up, industrial upgrading and innovation-driven development, and drive the coordinated development of middle and lower-reach provinces. Rely on Sichuan and Henan to build a "southwest-central plains" dual-core growth pole, radiating the upper, middle and lower reaches respectively to form a development framework of leading drive, multi-polar support and regional linkage. Meanwhile, establish a cross-regional coordinated development mechanism for the Yellow River Basin, break administrative barriers, promote the free flow and efficient allocation of talents, capital, technology and other factors, and gradually narrow the development gap between east and west.

Second, implement targeted and precise policies to remedy dimensional development shortcomings. For midstream resource-based provinces, focus on promoting industrial structure transformation and upgrading, foster strategic emerging industries and modern services, and get rid of resource dependence. For underdeveloped upper-reach provinces, increase central fiscal transfer payments and policy support, remedy shortcomings in transportation, medical care, public culture

and other infrastructure, build a solid ecological security barrier, and foster green industries such as ecotourism and characteristic agriculture. For the common shortcoming of cultural industry, deeply explore the resources of Yellow River culture, revolutionary culture and intangible cultural heritage, build a world-class Yellow River cultural tourism belt, foster leading cultural enterprises and characteristic IPs, and promote the transformation of cultural resources into industrial competitiveness.

Third, anchor innovation-driven and green development as the core to activate long-term development momentum. Take innovation capacity as the core engine for improving regional competitiveness, coordinate the layout of scientific and educational resources in the basin, establish cross-regional talent sharing and joint R&D mechanisms, increase R&D investment in upper-reach provinces, and foster new innovation-driven momentum. Coordinately promote ecological protection and pollution control across the basin, improve the ecological compensation mechanism, promote green and low-carbon transformation of traditional energy provinces, realize the transformation of ecological benefits into economic benefits, and build a solid ecological foundation and inject sustained momentum into the high-quality development of the Yellow River Basin.

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