Frontiers in Economics and Management Volume 5 Issue 4, 2024
ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

High-quality Economic Development Evaluation of Chinese Provinces based on Entropy Weight Method

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Abstract

High-quality economic development is crucial for a country or region to achieve sustainable prosperity, playing a significant role in improving people's living standards, promoting social progress, and enhancing national strength. This study focuses on six dimensions of economic growth: innovative development, coordinated development, green development, open development, and shared development. It constructs an evaluation index system for high-quality economic development at the provincial level in China and uses the entropy weight method to evaluate the high-quality economic development level of 30 provinces in China for the year 2021. The research finds significant disparities in high-quality economic development among Chinese provinces: coastal areas in the east lead, with the northeast, central, and southwest regions in the middle, and the northwest region relatively lagging behind. Therefore, future efforts should focus on strengthening regional cooperation and communication, relying on the unique advantages of each province to promote development that is both differentiated and balanced.

Keywords

High-quality Economic Development; Provinces and Regions; Entropy Weight Method; Evaluation Indicator System.

1. Introduction

Since the reform and opening up, the Chinese economy has entered a long period of rapid growth. During this period, despite significant achievements in economic construction, a series of problems have emerged, such as unbalanced regional development, irrational industrial structure, diminishing demographic dividend, and deteriorating ecological environment. With the deepening of globalization and the variability of the international situation, the uncertainty of the external environment has brought new challenges to the development of China's economy. Against this backdrop, transforming the mode of economic development has become a necessary condition for achieving sustained economic growth. The concept of high-quality economic development was first proposed at the 19th National Congress of the Communist Party of China, marking a shift from high-speed growth to high-quality growth in China's economic development. The Fifth Plenary Session of the 19th Central Committee further emphasized that during the "14th Five-Year Plan" period, the theme of economic and social development is to promote high-quality development. The transformation of the development model means that development goals and requirements change simultaneously. High-quality development aims to reduce the restrictive impact of unbalanced and inadequate economic and social development on the development of productive forces. Guided by the new development concepts of "innovation, coordination, green, openness, and sharing," it is a key measure to solve the main social contradictions.

ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

Considering the critical importance of high-quality regional economic development for the overall improvement of the national economy, to scientifically assess the level of high-quality economic development across China's provinces and explore the similarities and differences in their development patterns to enhance provincial competitiveness, this paper reviews related research and, based on an understanding of the essence of high-quality economic development, constructs an evaluation index system for high-quality economic development in China's provinces. It uses the entropy weight method to evaluate the level of high-quality economic development in 30 provinces of China and then proposes targeted countermeasures and suggestions based on the research findings.

2. Literature Review

In terms of evaluation indicators, the International Union for Conservation of Nature (IUCN) proposed as early as 1980 that to achieve sustainable development, it is necessary to comprehensively consider social, ecological, and economic factors[1]. This perspective defines sustainable development as a quality systemic attribute[2], drawing widespread attention. Based on this, many international scholars have proposed different evaluation criteria and systems from the perspective of sustainable development, but these do not fully adapt to the economic development system and goals with Chinese characteristics. Domestic researchers' measurement of the level of high-quality regional economic development is mainly divided into three categories: First, using single indicators for evaluation, such as representative indicators like labor productivity, total factor productivity, and efficiency of factor allocation. For example, Wu and Wei (2022) evaluated the high-quality economic development of the Yangtze River Delta based on green total factor productivity[3]; Liao and Wang (2019) measured the level of high-quality economic development of 282 Chinese cities through per capita real GDP[4]; Chen and Chen (2018) assessed the economic development level of 286 Chinese cities using labor productivity[5]. However, due to the limitations of single indicators, this method is difficult to comprehensively and objectively evaluate, and has not fully reflected the connotation of high-quality economic development. Second, based on the understanding of the connotation and characteristics of high-quality economic development, a multi-indicator comprehensive evaluation system is designed. For example, Ren and Cui (2022) constructed an evaluation system around seven dimensions: economic fundamentals, ecological environment, education level, job quality, medical level, urban construction, and urban-rural coordinated development, selecting 19 indicators[6]; Shi and Ren (2018) built indicators for high-quality economic development based on two dimensions: economic growth fundamentals and social outcomes[7]; Fang and Xu (2021) calculated the situation of high-quality economic development of cities in Jiangsu Province by integrating three dimensions: sustainability, coordination, and openness and sharing of economic development[8]; Zhao et al. (2024) constructed an evaluation indicator system for high-quality economic development from five dimensions: economic level, economic structure, economic efficiency, economic dynamics, and economic trade[9]. Third, taking the five directions of the new development concept as the basic dimensions, it is believed that these are the main factors affecting the level of high-quality economic development, and improvements are made accordingly. For example, Yang et al. (2021) evaluated the high-quality economic development of 27 central cities in the integration of the Yangtze River Delta in six dimensions: comprehensive quality and efficiency, innovation development, coordinated development, green development, open development, and shared development[10]; Ou et al. (2020) conducted an empirical study on the level of high-quality economic development of 21 prefecture-level cities in Guangdong Province based on the "Five Development Concepts"[11]; Liu and Lun (2023) studied the evolution of high-quality regional economic development in Hunan Province from 2009 to 2021 based on the new development concept[12]. These researches provide a reference for the construction of an evaluation index

ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

system for high-quality economic development at the provincial level. However, due to the complexity of the high-quality economic development issue, the index system under the same problem or perspective has not been unified, leaving room for improvement.

In terms of evaluation methods, comprehensive studies have shown that common methods for evaluating high-quality economic development include Analytic Hierarchy Process (AHP), Factor Analysis, Principal Component Analysis, and Entropy Weight Method, among others. Zhou and Tian (2022) used the factor analysis model to select main factors and conducted a comprehensive analysis of the economic development level of the Xinjiang region in 2019[13]; Yang (2021) calculated the high-quality economic development level of 16 prefectures in Yunnan Province from 2019 to 2020 through global principal component analysis[14]. However, factor analysis and principal component analysis use the logic of dimensionality reduction to process data, which might lead to the loss of some useful information. Cheng et al. (2022) used Structural Equation Modeling for indicator screening, model modification, and testing. By objectively assigning weights through factor loadings, they calculated the comprehensive evaluation coefficients of high-quality economic development for 31 provincial capitals in China[15]. Liu and Liu (2022) used the Analytic Hierarchy Process to conduct a spatial and temporal comparative study of the high-quality economic development of the six provinces in central China from 2009 to 2019[16]. However, the AHP relies on expert scoring, which is a form of subjective weighting and may affect the objectivity of the evaluation results. The entropy weight method, based on information entropy theory, can fully utilize data information and objectively reflect the importance of each indicator, thus attracting scholars' attention in the evaluation of regional economic high-quality development. Wang et al. (2022) used the entropy method to conduct a comprehensive evaluation of the high-quality economic development capabilities of 10 coastal provinces in China in 2018[17]. Ding et al. (2022) used the entropy weight ideal point method to calculate the high-quality economic development level of 30 provinces in China from 2007 to 2020[18]. Wang (2024) measured the high-quality development level of the open economy in Henan Province based on the entropy weight gray correlation analysis method[19]. These studies have verified the effectiveness of the entropy weight method in evaluating high-quality economic development, but these evaluation studies have limitations such as limited provincial samples and lack of recent data.

In light of this, this paper evaluates the high-quality economic development levels of 30 provinces in China (excluding Hong Kong, Macao, Taiwan, and the Tibet region due to the poor availability of data) in 2021 by employing the entropy weight method. First, it constructs an evaluation index system for the high-quality economic development of Chinese provinces. Next, it introduces the principle and calculation steps of the entropy weight method. Then, it collects and analyzes relevant data from each province, displaying the evaluation results. Finally, it proposes suggestions for high-quality economic development strategies.

3. Research Design

3.1. Construction of the Indicator System

The 5th Plenary Session of the 18th Central Committee of the Communist Party of China proposed a new development concept of "innovation, coordination, green development, openness, and sharing." The outline of the 14th Five-Year Plan, based on this concept, clearly defines high-quality economic development and reaffirms "promoting high-quality development" as the core task, insisting on implementing the new development concept. Therefore, "innovation, coordination, green development, openness, and sharing" become key directions for evaluating high-quality economic development. This paper selects the quality of economic growth, innovation development quality, coordinated development quality, green development quality, open development quality, and shared development quality as primary

ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

indicators and refers to existing research (Yang et al., 2021; Wu et al., 2023; Wei et al., 2023)[10, 20-21] to further refine secondary indicators and construct an evaluation system for high-quality economic development in Chinese provinces (see Table 1).

Table 1. Evaluation Indicator System for High-Quality Economic Development in Chinese Provinces

Primary Indicator	Secondary Indicator	Measurement Method	Attributes
Quality of economic growth	GDP per capita growth rate	(Current year GDP per capita - Last year GDP per capita) / Last year GDP per capita	+
	Fixed asset investment growth rate	(Investment in fixed assets during the reporting period - Fixed assets investment at the base period) / Fixed assets investment at the base period	+
	Labor productivity	GDP / Number of employed persons	+
Quality of innovative development	Intensity of R&D expenditure	R&D / GDP	+
	Number of patents owned	Number of patents per 10,000 people	+
	High-tech output	High-tech output value as a percentage of GDP	+
Quality of coordinated development	Advanced industrial structure	Output value of tertiary industry / Output value of secondary industry	+
	Urban-rural income ratio	Urban residents' income / Rural residents' income	-
	Urbanization rate	Urban permanent population / Total permanent population	+
Quality of green development	Energy consumption per unit of GDP	Total energy consumption (ton standard coal) / GDP	-
	Total energy consumption growth rate	(Current year energy consumption - Last year energy consumption) / Last year energy consumption	-
Quality of open development	Import and export value proportion	Total import and export volume / GDP	+
	Foreign investment amount	Total foreign investment	+
Quality of shared development	Education funding effort	Education expenditure / Budget expenditure	+
	Social security services	Social security and employment expenditure / Budget expenditure	+
	Healthcare investment	Healthcare expenditure / Budget expenditure	+

3.2. Entropy Weight Method and its Applications

The entropy weight method utilizes the concept of information entropy to determine the weights of various indicators by analyzing the distribution of indicator values. When the distribution of a certain indicator's values is more dispersed and uncertainty is greater, its weight is smaller; conversely, when the distribution is more concentrated and uncertainty is smaller, its weight is greater. This article applies the entropy weight method to calculate the weights of indicators for high-quality economic development across provinces, and then uses the additivity of entropy to calculate the indicator evaluation values through linear weighting.

Step 1: Standardize the original data, with the formula as follows:

ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

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

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

Formulas (1) and (2) correspond to positive indicators (the larger, the better) and negative indicators (the smaller, the better), respectively, where x_{ij} represents the original value of the j-th indicator of the i-th province, and r_{ij} represents the standardized value.

Step 2: Calculate the entropy value for each indicator based on the standardized data, using the following formula:

$$e_j = -k \times \sum_{i=1}^{m} P_{ij} \times \ln(P_{ij} + \Delta) \tag{3}$$

Among them, e_j represents the entropy value of the j-th indicator; $k = \frac{1}{\ln(m)}$ is a constant, m is the number of sample provinces evaluated; $p_{ij} = \frac{r_{ij}}{\sum_{i=1}^{m} r_{ij}}$ represents the proportion of the i-th province's j-th indicator among all samples of that indicator; Δ is a small amount introduced to overcome the zero values after data standardization and the excessive differences in weights, referring to the research by Zou and Han (2021)[22], this paper sets $\Delta = 0.005$.

Step 3: Calculate the weight of each indicator based on the entropy value, using the following formula:

$$\omega_j = \frac{1 - e_j}{\sum_{j=1}^{n} (1 - e_j)} \tag{4}$$

Where $1 - e_j$ represents the redundancy of information entropy, ω_j represents the weight of the j-th indicator.

Step 4: Calculating the evaluation value. Considering simplicity and effectiveness, a linear weighting model is used to calculate the comprehensive evaluation value of the corresponding indicators. Let H be the total score for high-quality economic development, then:

$$H = \sum_{j=1}^{n} \omega_j \times x_{ij} \tag{5}$$

3.3. Data Sources

This article takes the 30 provinces, autonomous regions, and municipalities directly under the Central Government of China as sample cases (Tibet is not included in the statistics due to some

ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

missing data). The data sources are from the National Bureau of Statistics of the People's Republic of China and the Ministry of Education website, as well as the "China Statistical Yearbook 2022," "China Science and Technology Statistical Yearbook 2022," and "China Foreign Economic Trade Statistics Yearbook 2022."

4. Empirical Analysis

4.1. Weight Analysis

According to calculations, the weightings of primary indicators for high-quality economic development in 2021 are shown in Figure 1. Among them, the highest weighting is given to "foreign investment amount" (0.14), reflecting the critical impact of the degree of foreign capital absorption on the level of economic development and emphasizing the importance of strengthening the introduction of foreign investment. Next is "number of patents owned" (0.11), highlighting the importance of enhancing the level of technological innovation development. In addition, based on the additivity principle of entropy, the weighted sum of subordinate indicators can obtain the weighting of superior indicators. It can be seen that the weightings of primary indicators are as follows: quality of economic growth (0.13), quality of innovation development (0.25), quality of coordinated development (0.18), quality of green development (0.07), quality of open development (0.22), quality of shared development (0.15). This indicates that the quality of innovation development in various provinces has the greatest impact on the level of high-quality economic development, followed by the quality of open development; the current impact of the quality of economic growth and green development on the level of high-quality economic development is relatively small and needs to be strengthened.

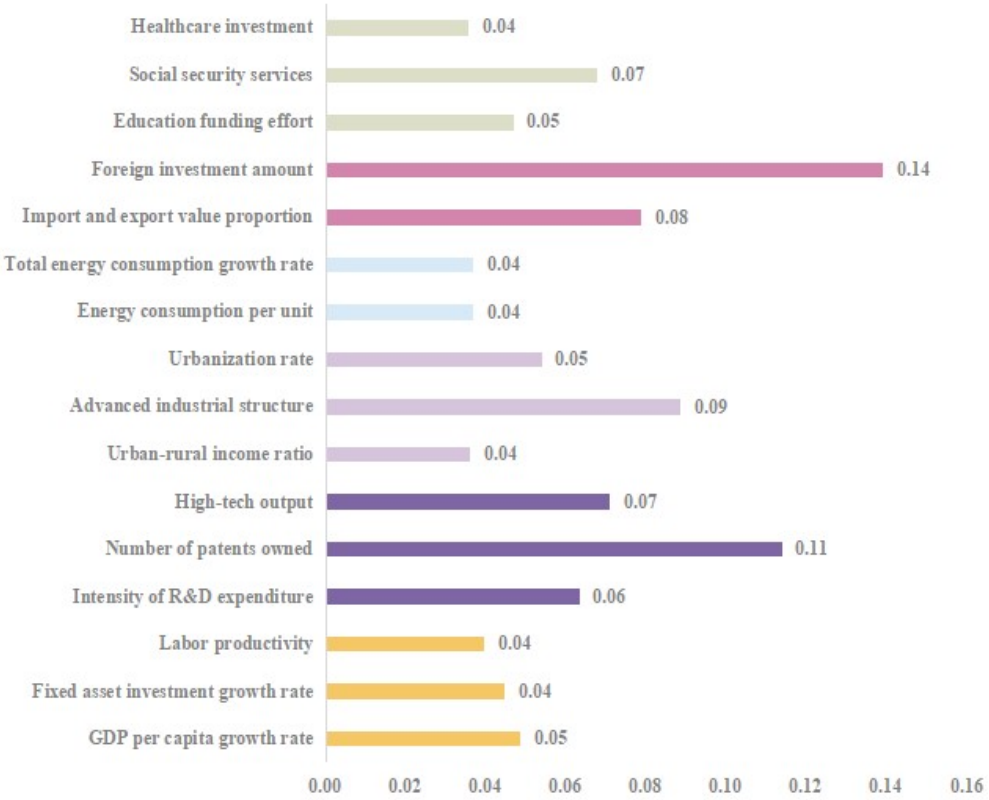
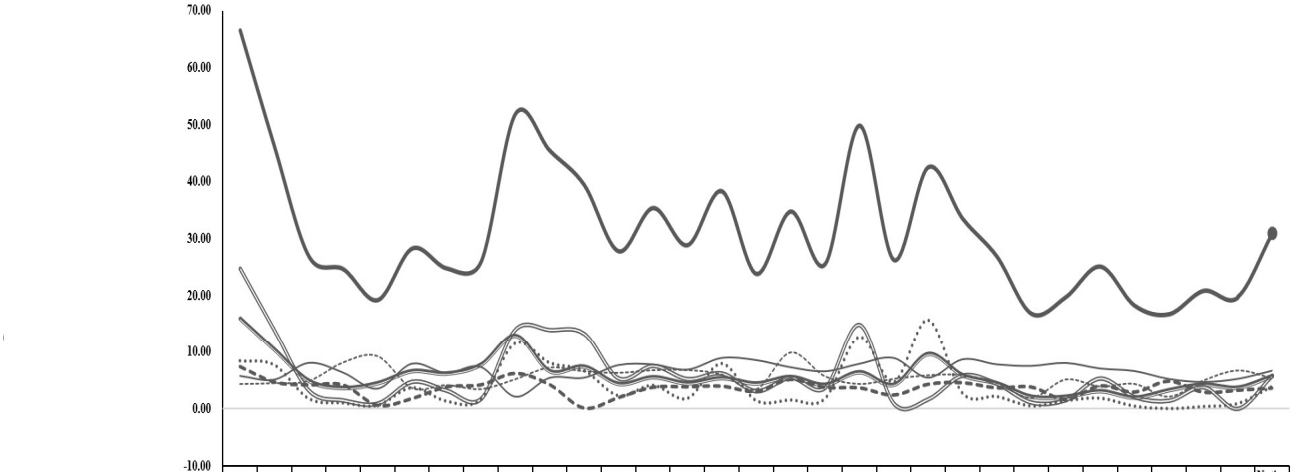


Figure 1. Basic Level Indicator Weights

ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

4.2. Overall Situation Analysis

(1) *Ranking situation*. The total score for high-quality economic development evaluation and the scores for each sub-item are shown in Figure 2. Ranked by the total score of high-quality economic development, Beijing (66.49), Shanghai (51.86), and Guangdong (49.83) occupy the top three positions. As China's capital and commercial financial center, respectively, Beijing and Shanghai have advantages in political status, abundant scientific research funding, a wealth of talent, developed foreign trade, and advanced industrial structures. They have formed significant competitive advantages in the quality of innovative development, coordinated development, and open development. Guangdong, a southeastern coastal province, has geographical advantages and places great emphasis on education investment and healthcare services. Its quality of innovative development and shared development is high, thus achieving good overall economic development quality.



	Beijing	Tianjin	Hebei	Shanxi	Inner Mongolia	Liaoning	Jilin	Heilongjiang	Shanghai	Jiangsu	Zhejiang	Anhui	Fujian	Jiangxi	Shandong	Henan	Hubei	Hunan	Guangdong	Guangxi	Hainan	Chongqing	Sichuan	Guizhou	Yunnan	Shaanxi	Gansu	Qinghai	Ningxia	Xinjiang	National Average
High-quality economic development	66.49	46.08	26.90	24.67	19.26	28.30	24.82	25.93	51.86	45.43	39.43	27.81	35.40	28.87	38.33	23.86	34.78	25.55	49.83	26.29	42.54	33.53	26.85	16.86	19.79	25.14	18.28	16.79	20.89	19.71	31.01
quality of economic growth	4.30	4.44	4.84	8.07	9.19	3.58	4.10	3.41	5.13	7.18	6.52	6.26	6.71	6.73	5.97	3.35	9.83	5.65	4.31	5.19	5.82	5.87	4.47	1.87	5.09	3.85	4.31	2.07	4.89	6.66	5.32
quality of innovative development	24.77	13.83	3.19	1.46	0.91	4.74	3.19	1.73	14.02	13.95	13.28	5.33	7.53	5.20	6.21	3.07	5.45	3.67	14.86	0.90	1.67	5.85	4.36	1.09	1.53	5.31	2.05	1.41	3.79	0.00	5.81
quality of coordinated development	15.92	10.40	4.93	3.69	4.53	6.63	6.21	7.77	12.89	6.62	7.41	4.39	5.56	4.51	5.40	4.47	5.61	4.24	6.44	4.26	9.64	5.90	4.50	2.16	2.17	3.14	2.01	3.31	4.28	3.75	5.76
quality of green development	7.38	4.68	4.18	4.17	0.61	1.79	3.83	4.18	6.19	4.24	0.13	1.95	3.77	3.85	3.96	3.05	5.14	3.74	3.67	2.42	4.29	4.56	3.66	3.81	1.63	4.00	2.93	4.83	2.92	3.24	3.63
quality of open development	8.43	7.70	1.76	1.00	0.57	3.70	1.31	1.57	11.57	8.08	6.72	2.28	4.10	1.78	7.93	1.42	1.52	1.73	12.71	4.67	15.74	2.73	2.13	0.47	1.38	1.84	0.43	0.00	0.37	0.89	3.88
quality of shared development	5.70	5.04	8.01	6.28	3.46	7.86	6.19	7.28	2.05	5.36	5.38	7.61	7.73	6.80	8.86	8.49	7.23	6.51	7.83	8.86	5.39	8.62	7.73	7.46	7.99	7.00	6.55	5.16	4.63	5.17	6.61

Figure 2. Evaluation Results of High-Quality Economic Development

(2) *Cluster Distribution*. To further study the distribution of high-quality economic development levels across provinces in terms of geographical space, and to explore the similarities between provinces at the same level, this article analyzes the cluster distribution of total scores for high-quality economic development levels. The total scores of high-quality economic development levels for each province range from 66.49 (Beijing) to 16.79 (Xinjiang), with an average (M) of 31.01 and a standard deviation (SD) of 11.94. By using (M+SD) and (M-SD) as the dividing criteria, calculated to be 42.95 and 19.07 respectively, all provinces in our country can be divided into three clusters based on their levels of high-quality economic development: top (total score above M+SD), middle (total score between M+SD and M-SD), and bottom (total score below M-SD) (see Table 2 for details). The results show that the eastern coastal provinces are the most optimal, followed by the northeast, central, and southwest provinces, with the northwest provinces being relatively backward.

ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

Table 2. High-Quality Economic Development Categories

Type	Top(>42.95)	Middle(19.07~42.95)	Bottom(<19.07)
Provincial Domain	Beijing, Tianjin, Shanghai, Jiangsu, Guangdong	Liaoning, Jilin, Hebei, Shanxi, Inner Mongolia, Heilongjiang, Zhejiang, Anhui, Fujian, Jiangxi, Shandong, Henan, Hubei, Hunan, Guangxi, Hainan, Chongqing, Sichuan, Yunnan, Shaanxi, Ningxia, Xinjiang	Qinghai, Guizhou, Gansu

4.3. Sub-dimension Analysis

(1) *Scoring Performance*. Figure 2 shows the scores for each sub-dimension (i.e., primary indicators), which are the weighted scores reflecting the strengths and weaknesses of provinces in various development dimensions, as well as collectively indicating the composition of the total score for high-quality economic development levels. The province with the highest quality of economic growth score is Hubei, while the lowest is Guizhou; the highest quality of innovation development score goes to Beijing, with the lowest in Xinjiang; the highest quality of coordinated development score is Beijing, with the lowest in Gansu; the highest quality of green development score is Beijing, while the lowest is Zhejiang; the highest quality of open development score belongs to Hainan, with the lowest in Qinghai; the highest quality of shared development score is in Guangxi, with the lowest in Shanghai. Due to the low rankings in multiple dimensions, Guizhou, Gansu, and Qinghai are at the bottom of the evaluation scores for high-quality economic development.

(2) *Cluster Analysis*. This paper uses the SPSS26 system for systematic clustering of scores on various sub-dimensions (Ward method) to further examine the similarities and differences in scores across dimensions, identifying five development patterns (see Table 3).

Table 3. Clustering of Scores by Primary Indicator Dimensions

Type	Provincial Domain
Multidimensional breakthrough	Beijing
Open development	Hainan
Balanced development	Fujian, Chongqing, Hubei, Shandong
Innovative and open	Jiangsu, Zhejiang, Tianjin, Guangdong, Shanghai
Mediocre development	Hebei, Sichuan, Henan, Shaanxi, Jiangxi, Hunan, Ningxia, Anhui, Jilin, Heilongjiang, Liaoning, Guangxi, Yunnan, Gansu, Guizhou, Qinghai, Shanxi, Xinjiang, Inner Mongolia

Beijing's overall score for high-quality economic development is superior, due to its leading scores in innovation, coordinated, and green development. This is highly related to Beijing's status as a national administrative and cultural center, representing a multi-dimensional breakthrough development model. Hainan, as the largest special economic zone in China, has a vast economic hinterland and has received a series of high-level opening-up policies such as 'zero tariff', financial openness, and tax incentives. This special economic status and policy convenience grant Hainan significant advantages in attracting foreign investment, expanding openness, and promoting economic innovation, making it top in the quality of open development, known as a strong open development model. Provinces represented by Chongqing, Shandong, and Hubei have nearly balanced scores in all sub-categories and a higher level of shared development, ranking them in the middle in terms of high-quality economic development, known as a balanced development model. Provinces represented by Jiangsu, Zhejiang, and Shanghai mainly rely on innovation and open development for their high-quality economic development scores, with clear advantages, closely related to their location in the

ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

southeastern coastal region and their developed economy with ample capital, known as an innovative and open model. Provinces represented by Liaoning, Hebei, and Shaanxi have lower scores in multiple sub-conditions, with occasionally one higher score, but lack a distinctive focus, leading to their high-quality economic development scores being in the lower middle range, considered as a mediocre development model.

5. Conclusion

This paper establishes an indicator system to evaluate the high-quality development of provincial economies in China, covering six dimensions of economic growth, innovation, coordination, green development, openness, and sharing. The entropy weight method is used to evaluate 30 provinces. The research results show: firstly, the quality of innovative development is the most critical dimension affecting high-quality economic development, followed by openness, coordination, and sharing development quality, while the impact of economic growth and green development quality is relatively weaker at present. Secondly, there are significant differences in the scores of different provinces in high-quality economic development, with Beijing, Shanghai, and Guangdong ranking top three. Through the analysis of sample means and standard deviations, the 30 provinces can be divided into three groups of high, medium, and low, with coastal provinces performing better and northwest provinces relatively poorer. In addition, by analyzing the scores of various primary indicators, five different development patterns are identified.

Based on the research conclusions above, to enhance the high-quality development of the economy in various provinces and regions, this article suggests:

(1) Promoting technological innovation. The quality of innovative development has a decisive impact on high-quality economic development, which means that innovation is the key force driving high-quality economic development and should be given full attention. Beijing has performed outstandingly in the aspect of "quality of innovative development", partly due to its numerous universities, abundant talent resources, sufficient research funding, and sound innovation policies, providing references for other provinces. In the future, provinces can appropriately increase investment in education and research funding, improve mechanisms for cultivating and attracting high-level talents to provide intellectual support for regional economic development; strengthen the protection of intellectual property rights, optimize the innovation environment, and create a good atmosphere for innovation; improve the technology innovation system led by enterprises, market-oriented, deeply integrated with production, learning, and research, and establish relevant mechanisms to promote the transformation and application of scientific and technological achievements.

(2) Enhancing economic growth and the quality of green development in two dimensions. The greening of the economy helps to allocate resources more efficiently and improve resource utilization. Compared to traditional development models, green development emphasizes efficient, harmonious, and sustainable economic progress. For example, Beijing's achievements in green development, such as accelerating the transformation of high-energy-consuming industries and increasing investment in green low-carbon industries, provide valuable experiences for other provinces to learn from. Regions can reduce their dependence on natural resources by promoting energy-saving technologies, developing a circular economy, and promoting measures such as resource recycling. By strengthening pollution monitoring and conducting ecological restoration projects, they can ensure the coordination of economic development and environmental protection, achieving sustainable development.

(3) Encouraging personalized development. Each province should analyze its own economic development strengths and weaknesses, utilize local resources and industrial foundations, formulate personalized development strategies, and take targeted measures to leverage its own

ISSN: 2692-7608 DOI: 10.6981/FEM.202404_5(4).0002

advantages. For example, coastal areas can utilize their port advantages to promote foreign trade and attract foreign investment; inland areas can develop agricultural and mineral resources to drive the development of distinctive industries. At the same time, macroeconomic policy-making should enhance flexibility and adaptability, providing space for provinces to pursue differentiated development.

(4) Strengthen cooperation and coordination among provinces. Research shows significant differences in the high-quality economic development levels among provinces, with a total score gap of 49.7 points between Beijing and Xinjiang, highlighting the issue of regional development imbalance. Establishing communication and coordination mechanisms and cooperation platforms (such as regional cooperation forums, industry alliances, etc.) can promote information sharing. Provinces with high levels of development should play a leading role within economic zones, promoting cooperation in areas such as industrial development, infrastructure construction, and environmental protection through policy coordination mechanisms to achieve policy complementarity and regional integrated development. Through industrial chain cooperation, resource sharing and complementary advantages can be achieved, promoting mutual benefits.

Acknowledgments

College Students' Innovation and Entrepreneurship Training Program from University of Science and Technology Liaoning (Project title: Research on the Configurational Impact of the Business Environment in Chinese Provinces on High-Quality Economic Development).

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