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A Comprehensive Evaluation of High-Quality Economic Development in China's Northeast Region in the New Era

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Abstract: *In the context of advancing the comprehensive revitalization of the Northeast in the new era, this study focuses on the three provinces within the region of China. It endeavors to establish an evaluation index system for high-quality development, encompassing economic growth and potential, innovation capability and technological progress, ecological sustainability and environmental protection, as well as social infrastructure and public services. By analyzing the data from 2015 to 2022 using the entropy weight-VIKOR method, the level of high-quality economic development in the Northeast region was assessed. The study finds that the overall level of high-quality economic development in the Northeast region is continuously improving, but there are differences between the provinces, and there are certain shortcomings in development. Based on this, suggestions for expanding open cooperation, adhering to green and sustainable development, and promoting in-depth development of innovation and entrepreneurship are proposed, in order to promote high-quality economic development in the Northeast region, and achieve the goal of comprehensive revitalization.*

Keywords: *High-quality economic development, Northeast region of China, Entropy method, VIKOR*

1. Introduction

The Northeast region, a pivotal area in China's strategic landscape, has witnessed a resurgence in high-quality economic development since the introduction of the "Fourteenth Five-Year" comprehensive revitalization plan. Assessing the level of high-quality development in the Northeast holds significant importance as China's economy has transitioned from rapid growth to a focus on quality. Research endeavors have shifted towards evaluating the "quality" of economic growth, encompassing the formulation of evaluation frameworks and identification of influencing factors. Scholars have predominantly constructed an index system rooted in the "Five Development Concepts" of the new era: innovation, coordination, environmental sustainability, openness, and inclusivity [1]. In 2022, Lingming Chen and Congjia Huo utilized principal component analysis to delve into the factors shaping high-quality economic development. Their findings underscored the necessity of fostering technological innovation, enhancing innovation mechanisms, and promoting inter-provincial cooperation to mitigate development disparities [2]. Similarly, Dunping Huang and Lei Ye, in the same year, devised a five-dimensional evaluation index system. Employing factor and cluster analysis, they evaluated the high-quality development of 58 prefecture-level cities in the Yellow River Basin, revealing that downstream areas exhibited higher comprehensive factor scores indicative of high-quality economic development [3].

However, research on the high-quality development of China's Northeast region is relatively insufficient. Yunlai Dong's research focused on the economic development of Liaoning's county-level regions and found that the area faces prominent issues such as a generally small scale, low urbanization level, suboptimal industrial structure, and intensified population loss [4]. Guanghui Li and Qihua Cai used the "Entropy Weighted-TOPSIS" method and found that Heilongjiang Province's coordinated development index and green development index have continued to grow, while the innovation development index, shared development index, and openness development index need to be optimized and adjusted [5]. Hongfu Ding and others used an improved entropy weighting method to measure and analyze the high-quality economic development level of the Northeast region from 1998 to 2019 and found significant spatiotemporal differences in the high-quality development levels of various regions in different periods [6-7].

In summary, research on the high-quality development of China's Northeast region is limited, with

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recent studies being relatively insufficient. Therefore, this paper focuses on the three northeastern provinces, constructing a scientific evaluation index system to measure their high-quality development levels. It also analyzes the intrinsic mechanisms and key factors influencing this development. These efforts will have significant theoretical and practical implications.

2. Construction of an indicator system for high-quality economic development

High-quality development is defined as the ability to meet the people's growing needs for a better life, reflecting the new development concept. In 2018, Lifeng He, then Director of the National Development and Reform Commission, proposed four aspects of high-quality development: prioritize quality to achieve a high level of economic circulation; prioritize efficiency to promote the effective allocation of resources; prioritize innovation to unleash full vitality; prioritize co-creation and sharing to achieve people-centered development. This paper draws on Lifeng He's views, in conjunction with the actual development of the three Northeast provinces, from the four dimensions of economic growth and potential, innovation capacity and technological progress, ecological sustainability and environmental protection, social infrastructure and public services, constructs an evaluation index system for the high-quality economic development of the Northeast region.

1) Economic growth and potential are crucial indicators for measuring regional economic vitality and potential growth. This paper selects seven indicators to measure the level of economic growth and potential: per capita GDP, GDP growth rate, the proportion of tertiary industry in GDP, total import and export volume, Engel coefficient of residents, general public budget expenditure, and per capita disposable income of residents.

2) Innovation capacity and technological progress are key drivers for promoting high-quality economic development. We have chosen four indicators to measure the level of innovation capacity and technological progress: the number of patent applications granted, the proportion of R&D expenditure in GDP, the turnover of the technology market, and the number of higher education students per capita.

3) Ecological sustainability and environmental protection are the foundation for achieving sustainable development. Rational resource utilization, pollution reduction, and ecosystem protection are crucial for long-term development. Therefore, we have selected three indicators to measure the level of ecological sustainability and environmental protection: forest coverage rate, energy consumption per unit of GDP, and the amount of chemical oxygen demand (COD) in industrial wastewater.

4) Social infrastructure and public services are important guarantees for supporting economic development. Investing in infrastructure construction and improving the level of public services help to enhance the quality of life for residents and promote comprehensive economic and social development. We measure the level of social infrastructure and public services using four indicators: the number of hospital beds per capita, the number of regular higher education institutions, the volume of public library collections per capita, and the number of public buses in operation.

3. Research Methodology for High Quality Economic Development

3.1 The Research Ideas on High-Quality Economic Development in Northeast China

This study aims to evaluate the level of high-quality economic development in the Northeast region, addressing the relative lack of economic development in the area, and conducting a comprehensive and integrated assessment. We face challenges in data acquisition, the appropriateness of indicator selection, the complexity of multidimensional data analysis, and the correlation between different indicators. Most existing studies refer to established evaluation indicator systems by scholars, such as methods based on the "Five Development Concepts" or objective evaluation methods like the entropy weight-TOPSIS method proposed by Guanghui Li and Qihua Cai [5], the factor analysis method by Dunping Huang and Lei Ye [3], and the principal component analysis used by Lingming Chen, and Congjia Huo [8]. However, in this study, we have adopted the entropy weight-VIKOR method, which can comprehensively consider the importance and performance of each indicator, suitable for multi-indicator comprehensive evaluation. Through the entropy weight-VIKOR method, we can objectively determine the weights of each indicator, thus comprehensively considering the importance of each indicator when evaluating the high-quality economic development level of the Northeast region. This method combines objective data analysis with the researcher's subjective judgment, allowing for the addition of subjective elements according to actual needs when discussing the level of high-quality economic development.

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3.2 Research Method for High-Quality Economic Development in the Northeast Region

As shown in Table 1, there are four primary indicators for measuring the level of high-quality economic development, encompassing 18 secondary indicators. This paper employs the entropy weight - multi-criteria compromise ranking method (abbreviated as entropy weight-VIKOR) to calculate the level of high-quality economic development in the three northeastern provinces of China from 2015 to 2022.

3.2.1 Entropy Weight Method

The entropy weighting method, widely used across various fields, determines the weights of each indicator based on data differentiation using an entropy calculation formula[9-11]. This method objectively reflects the utility value of sample information entropy without introducing subjective biases. It involves standardizing the data in the scoring matrix, calculating the entropy values for each indicator, and then computing their respective weights.

This paper initially processes the data through dimensionless treatment to convert it into a unified measurement unit.

Positive indicators:

$$X'_{ij} = \frac{x_{ij} - \min(x_{ij})}{\max(x_{ij}) - \min(x_{ij})} \tag{1}$$

Negative indicators:

$$X'_{ij} = \frac{\max(x_{ij}) - x_{ij}}{\max(x_{ij}) - \min(x_{ij})} \tag{2}$$

In the formula: $X_{ij}(i = 1,2,\dots,n; j = 1,2,\dots,m)$ represents the specific data for the $i\,th$ high-quality economic development indicator in the$j\,th$ indicator.

Next, calculate the proportion Y_{ij} and the entropy value e_j for the $j\,th$ indicator of the $i\,th$ high-quality economic development indicator data X'_{ij}.

$$Y_{ij} = \frac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}} \tag{3}$$

$$e_j = -\frac{1}{\ln m} \times \sum_{i=1}^{m} \left(Y_{ij} \ln Y_{ij}\right) \tag{4}$$

Finally, calculate the weight w_j of the $j\,th$ indicator:

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j} = \frac{1 - e_j}{n - \sum_{j=1}^{n} e_j} \tag{5}$$

where $d_j = 1 - e_j, d_j(j = 1,2,\dots,n)$ represents the information redundancy of indicator j, the larger d_j is, the more important indicator j is; n represents the number of indicators.

3.2.2 VIKOR

VIKOR is a multi-attribute optimisation decision making method proposed by Opricovic et al, in 1998, which is a method for optimal compromise solution in multi-attribute decision making, as well as a method based on the ideal point method of decision making [12]. In the VIKOR method, the ranking of evaluation schemes is completed by comparing the group utility value, individual regret value, and strategic weight coefficient, through which the region with the closest proximity to the ideal region is selected for optimal high-quality economic development.

For each indicator $j = 1,\dots,n$, the best f_{ij} is designated as f_j^*, and the worst f_{ij} is designated as f_j^-. Use the equation to calculate the indices f_j^* and f_j^- for the indicators.

$$\begin{cases} f_j^* = \max\limits_i f_{ij} \\ f_j^- = \min\limits_i f_{ij} \end{cases} i = 1,\dots,m, j = 1,\dots,n \tag{6}$$

Using the formula, the group effect value (S_i) and individual regret value (R_i) for each alternative region can be obtained:

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$$S_i = \sum_{j=1}^{n} w_j \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)};\ \ i = 1, \dots, m \tag{7}$$

$$R_i = \max_j \left[w_j \frac{(f_j^* - f_{ij})}{(f_j^* - f_j^-)} \right];\ \ i = 1, \dots, m, j = 1, \dots, n \tag{8}$$

In the formula: f_j^* , f_j^- are the positive and negative ideal solutions for the $j\,th$ evaluation indicator, respectively; w_j is the weight of the evaluation indicator obtained by the entropy weighting method.

The benefit ratio value (Q_i)is calculated as follows:

$$Q_i = v \times \left[\frac{(S_i - S^*)}{(S^- - S^*)} \right] + (1 - v) \times \left[\frac{(R_i - R^*)}{(R^- - R^*)} \right] \tag{9}$$

In the formula: $S^* = \min_i S_i$; $S^- = \max_i S_i$; $R^* = \min_i R_i$; $R^- = \max_i R_i$, where v represents the strategy weight coefficient, $v \in [0,1]$. If $v > 0.5$, it indicates that decisions are primarily based on maximizing collective benefits; if $v < 0.5$, decisions are mainly based on minority dissenting opinions; if $v = 0.5$, both collective benefits and individual regrets are considered. In this study, $v = 0.5$. $Q_i \in [0,1]$, and smaller values indicate better results.

3.3 Analysis of the results of high-quality economic development in the Northeast region

Firstly, the weights calculated by the entropy weight method show (Table 1), among the factors affecting the high-quality economic development of the Northeast region, indicators such as total import and export volume, forest coverage rate, number of patent authorizations, number of higher education students per capita, and number of general higher education institutions have higher weights, indicating that international open cooperation, green and sustainable development, and creative and innovative development are crucial for the economic development of the Northeast region. Among them, the total import and export volume holds the greatest weight among all indicators, meaning that the high-quality economic development of the three northeastern provinces is closely related to their international trade activities. Considering that the three northeastern provinces are adjacent to Russia, Japan, and South Korea, and Heilongjiang and Shenyang have ports, with Jilin having added the Russian Vladivostok port in 2023 as a transshipment port for domestic goods cross-border transportation. This indicates that they possess significant resources and geographical advantages related to international trade, consistent with the view in the entropy weight method where the total import and export volume occupies the largest weight. The presence of customs ports provides these provinces with more convenient and efficient trade channels, promoting the vitality of import and export trade and contributing more significantly to the high-quality economic development.

Table 1: Indicator System and Weights for High-Quality Economic Development Level in the Northeast Region

Goal Layer	Criterion Layer	Indicator Layer	Indicator Attribute	Indicator Layer Weight (%)	Criterion Layer Weight (%)
High-Quality Economic Development Level of the Northeast Region	Economic Growth and Potential	Per Capita GDP	+	4.4	34.6
		GDP Growth Rate	+	1.9	
		Proportion of GDP from the Tertiary Sector	+	1.8	
		Total Import and Export Volume	+	14.2	
		Engel Coefficient of Residents	-	3.4	
		General Public Budget Expenditure	+	3.8	
		Per Capita Disposable Income of Residents	+	5.1	

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	Innovation Capability and Technological Progress	Number of Patent Authorizations	+	7.3	26.3
		Proportion of R&D Expenditure to GDP	+	6.2	
		Technology Market Transaction Volume	+	5.8	
		Number of Higher Education Students per Capita	+	7	
	Ecological Sustainability and Environmental Protection	Forest Coverage Rate	+	9.1	17.6
		Energy Consumption per Unit of GDP	-	6.7	
		Chemical Oxygen Demand (COD) Emission in Industrial Wastewater	-	1.8	
	Social Infrastructure and Public Services	Number of Hospital Beds per Capita	+	3.9	21.5
		Number of General Higher Education Institutions	+	7	
		Public Library Holdings per Capita	+	3.9	
		Number of Operating Public Buses	+	6.7	

Based on the VIKOR method results (see Table 2), we rank the regions' high-quality economic development levels in ascending order of Qi, with the top-ranked regions considered superior. As shown in Figure 1, the high-quality economic development of the three northeastern provinces has generally increased annually, despite some differences. Liaoning Province leads in high-quality economic development among the three, establishing an effective model. Its benefit ratio (Q) decreased from 0.339 in 2015 to 0.005 in 2022, demonstrating significant growth. Following the National Development and Reform Commission's 2016 initiative to promote six reform and innovation measures, the “14th Five-Year Plan” national science and technology innovation deployment, and the "14th Five-Year Plan and the 2035 Long-Range Objectives Outline for the National Economy and Social Development of Liaoning Province," Liaoning has intensified its innovation-driven development strategy. This includes increasing institutional and mechanism innovation efforts and accelerating the construction of a high-level innovative province. By 2022, Liaoning’s indicators of innovation capability and technological progress have significantly improved compared to 2015. The technology market transaction volume rose by 263%, patent authorizations increased by 207%, R&D expenditure as a proportion of GDP grew by 68%, and the number of higher education students per capita increased by 36%.

Heilongjiang and Jilin provinces have also made progress in high-quality economic development, although not as rapidly as Liaoning Province. Since 2015, their indicators of high-quality economic development have generally trended upward. Heilongjiang's benefit ratio (Q) decreased from 0.925 in 2015 to 0.407 in 2022, while Jilin's benefit ratio (Q) decreased from 0.984 in 2015 to 0.724 in 2022. Despite the slower pace compared to Liaoning, both provinces are actively promoting high-quality economic development in line with the “12th Five-Year Plan” for the revitalization of the Northeast. Guided by Deng Xiaoping Theory and the “Three Represents” thought, and implementing the scientific outlook on development, they are accurately focusing on scientific development and transforming their economic development modes, with only slight differences in speed.

Overall, the Northeast region has made significant strides in high-quality economic development.

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However, the disparities in development levels between provinces have been increasing yearly (as shown in Figure 2). These regional development gaps result in uneven resource allocation, which negatively impacts the high-quality economic growth of the entire Northeast region. Therefore, optimizing relevant policies to achieve coordinated regional development is essential.

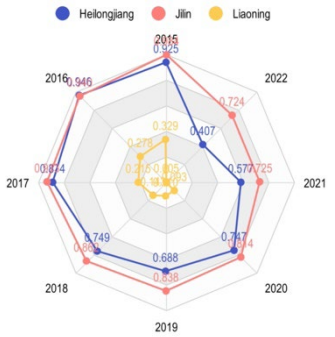

Figure 1: Ratio of utility ratio value (Q) by province in the Northeast region

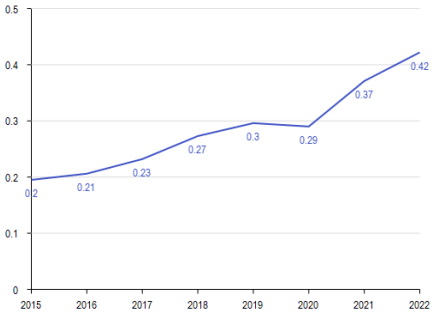

Figure 2: Gini Coefficient of the High Quality Economic Development Index for the Northeast Region

Table 2: VIKOR Ranking of High-Quality Economic Development Levels in the Northeast Region

Province & Year	**Group Utility Value (S)**	**Individual Regret Value (R)**	**Utility Ratio Value (Q)**	**Ranking**
Heilongjiang 2015	0.7477	0.1373	0.9249	21
Heilongjiang 2016	0.725	0.1416	0.9463	23
Heilongjiang 2017	0.6885	0.1377	0.8741	19
Heilongjiang 2018	0.6569	0.128	0.7494	15
Heilongjiang 2019	0.6169	0.1255	0.6883	11
Heilongjiang 2020	0.6083	0.1323	0.7472	14
Heilongjiang 2021	0.5241	0.1229	0.5765	10
Heilongjiang 2022	0.4859	0.1092	0.4068	9
Jilin 2015	0.7829	0.14	0.984	24
Jilin 2016	0.7449	0.139	0.9395	22
Jilin 2017	0.7246	0.1382	0.9131	20
Jilin 2018	0.6928	0.136	0.8616	18
Jilin 2019	0.654	0.1373	0.8378	17
Jilin 2020	0.6239	0.1377	0.8141	16
Jilin 2021	0.5766	0.1331	0.725	13
Jilin 2022	0.5878	0.1319	0.7241	12
Liaoning 2015	0.5898	0.0914	0.3287	8
Liaoning 2016	0.535	0.0914	0.2778	7
Liaoning 2017	0.4674	0.0914	0.2152	6
Liaoning 2018	0.398	0.0906	0.143	5
Liaoning 2019	0.3543	0.0914	0.1102	4
Liaoning 2020	0.3447	0.0906	0.0935	3
Liaoning 2021	0.2439	0.0906	0	1
Liaoning 2022	0.2498	0.0906	0.0054	2

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4. Conclusions and Policy Recommendations

This study focuses on the three provinces of the Northeast region of China, based on the new development concept, constructs an evaluation index system for the high-quality economic development of the Northeast region from four dimensions: economic growth and potential, innovation capability and technological progress, ecological sustainability and environmental protection, and social infrastructure and public services. It uses the entropy value-VIKOR method to measure the level of high-quality economic development in the Northeast region. The following conclusions are drawn:

1) The overall high-quality economic development level of the Northeast region is continuously improving. Analyzing each province individually, it is found that the high-quality economic development level of each province has increased, but there are significant differences between the provinces. These differences are increasing year by year, showing a pattern of "low in the middle, high on both sides".

2) In terms of the importance diagnosis of indicators, the following regional economic high-quality development indicators rank in the top five: total import and export volume, forest coverage rate, number of patent authorizations, number of higher education students per capita, number of general higher education institutions.

Through the above research, it has been found that there are still deficiencies in the high-quality economic development of each province in the Northeast region, and the concept of overall coordinated development has not yet been formed. To achieve high-quality economic development in the Northeast region, it is necessary not only to plan comprehensively but also to adapt to local conditions. Therefore, the following policy recommendations are proposed:

Expand open cooperation: Relying on the locational advantages of the "Belt and Road," the China-Japan-Korea Free Trade Area, and the China-Mongolia-Russia Economic Corridor, promote high-quality open development in the Northeast region.

Adhere to green and sustainable development: As an important ecological security barrier in northern China, the Northeast region has continuously strengthened the protection of key ecological functional areas such as forests, wetlands, and grasslands in recent years, solidly advanced the battle against pollution for blue skies, clear waters, and clean soil, achieving significant results in the management of mountains, rivers, forests, fields, lakes, and grasslands, with a noticeable improvement in ecological environment quality. We adhere to the concept that "lucid waters and lush mountains are invaluable assets," committed to enriching the country through green development and benefiting the people with green policies, providing the public with more high-quality ecological products, promoting the formation of green development and lifestyles, and achieving harmonious development between humans and nature.

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