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Measurement of the High-Quality Development Level of the Heilongjiang Free Trade Zone

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Abstract: As northernmost pilot free trade zone of China and the first established in a border region, the China (Heilongjiang) Pilot Free Trade Zone has been entrusted with the critical mission of "building new heights in opening-up to the north" and the strategic positioning of serving as a central hub for cooperation with Russia and the broader Northeast Asia region. Against the backdrop of China's efforts to create a new landscape of opening-up, higher requirements have been set for the high-quality development of the Heilongjiang Pilot Free Trade Zone. Using principal component analysis, this study evaluates the high-quality development level of the zone based on the five new development concepts and 20 secondary indicators. It analyzes the contribution of each indicator to high-quality development, identifies high-frequency influencing factors, and proposes corresponding policy recommendations for future advancement. Research finds that: First, the development level of the Heilongjiang Pilot Free Trade Zone has achieved progress, with multiple factors promoting high-quality performance and a steady improvement in the economic foundation. Second, the growth dynamics have gradually shifted from a singular model to a multi-wheel drive mode, which characterized by "scale foundation+innovation efficiency+green sharing". Third, there are still some shortcomings: the contribution of technical personnel to the region's high-quality development needs to be improved, and there is a risk of losing highly skilled talent.

1. Introduction

The 19th National Congress reported: "China's economy has changed from a stage of high-speed growth to a stage of high-quality development". This shows that building a powerful socialist modern country should appreciate the quantity and quality of economic growth.

In 2013, China's first free trade zone, the Shanghai Free Trade Zone (FTZ), was officially established. By 2025, China has formed 22 FTZs. As a test field and stress test platform, the FTZ carries the strategic task of building a new highland and creating a new pattern of China's opening up and development. The pilot free trade zone has a special mission in advancing high-quality development.

Heilongjiang Free Trade Pilot Zone (FTZ) is the northernmost FTZ in China. It was approved to

be established in 2019. Its strategic positioning is to build a "central hub for regional cooperation with Russia and Northeast Asia", and bear the major responsibility of reform, opening up, innovation and development in promoting the comprehensive revitalization of the Northeast. In the new stage of the 15th Five-Year Plan, the development quality of the Heilongjiang Free Trade Zone is directly related to the implementation effect of the regional coordinated development strategy, and is also of exemplary importance to the promotion of China's strategy of opening up the border openness.

2. Relevant Concepts and Literature Review

2.1. Relevant Concepts

Free Trade Zone (FTZ) include two primary forms. The first is a designated area outside the customs territory, in which all or most import and export goods are exempt from tariffs. The second form is the Free Trade Area (FTA), A group of countries sign a free trade agreement, which represents a stage of regional economic integration. The definition in this article corresponds to the former (FTZ).

The concept of high-quality development was first introduced at the 19th National Congress. This report pointed out that "China's economy has shifted from a phase of rapid growth to a phase of high-quality development". In 2020, this concept was further enriched to contain several aspects such as the economy, society, culture, and ecology. However, there is not yet a unified definition. Generally speaking, it emphasizes high-quality economic development, which requires both reasonable quantitative growth and steady qualitative improvement.

2.2. Literature Review

According to existing scholarship, domestic and international research exists on the measurement of high-quality development levels and Free Trade Zone (FTZ). This study can be commonly categorized as follows.

First, regarding the assessment research on the level of high-quality economic development. Currently, no consensus exists among academics on the establishment of a measurement system for high-quality development levels. In terms of indicator selection and research scope, some researchers, such as Cubas et al. (2016), use total factor productivity (TFP) as a single indicator to measure the economic development quality[1]; Zhang Tao (2020) measures economic development quality in specific local regions[2]; other scholars, like Mlachila et al. (2017), have constructed a quality system for economic growth[3]; and Gong Piming (2023) builds a related measurement framework based the overall perspective of high-quality development[4].

Second, research pertaining to Free Trade Zone (FTZ). The economic effects of FTZ are the focus of most scholars' research. Internationally, Ravikumar Sunkara (2016) argues that establishing FTZ can generate trade creation effects, promote India's trade development, thereby increasing foreign exchange earnings and positively impacting its economic growth[5]; Whalley J (2016) contends that the Shanghai FTZ facilitates the opening of China's capital market, further promoting the economic structure adjustment[6]; Hossini S A et al. (2022) argue that FTZ positively impact regions in terms of attracting foreign investment, regional economic development, and increasing social welfare[7]. Domestic research indicates that effects manifest in two primary ways: On the one hand, they shows that it can directly drives economic growth in the host city. As noted by Wang Aijian et al. (2020), who state that the institutional innovation of FTZ significantly promotes regional economic growth[8]. Ye Linli (2020) points out that FTZ have a sustained effect on promoting regional economic growth with the effect strengthening over time[9]. On the other hand,

FTZ generate indirect growth effects which occurs through spatial spillovers to surrounding regions. Cui Riming et al. (2021) provide empirical confirmation. Their research finds that cities within 50-100 kilometers of an FTZ experience significant economic growth effects due to positive spillovers from the FTZ[10]. Other studies focus on the impact of FTZ on innovation and trade. Xu Jiexiang et al. (2020), through quantitative analysis, conclude that the establishment of FTZ promotes the enhancement of district innovation capacity and improves the quality of innovation within the zones[11].

2.3. Comment of Research Literature

According to domestic and international research, the measurement system for high-quality development level has not yet been fully unified. However, most of them still build the evaluation system around the five major aspects of “innovation, coordination, green, openness and sharing”. These researches mainly concentrates on their impact on regional economic growth and their radiating and driving effect on the economies of surrounding areas. Nevertheless, there are still relatively few articles on the construction of a measurement system for the high-quality development level of the Heilongjiang FTZ.

3. The High-quality Development of the Heilongjiang Free Trade Zone

Previous discussions have established the external context for analyzing the Heilongjiang FTZ. This section will elaborate its high-quality development through five key dimensions

3.1. Institutional Innovation and Development

Institutional innovation serves as the core driver for liberating and developing social productive forces, and the high-quality development of FTZ inherently relies on the deep empowerment of such innovation. The Heilongjiang Pilot FTZ has systematically advanced institutional innovation reforms, focusing on the key areas: optimized fiscal services.

On the fiscal system, the Harbin area utilized provincial advantages and foreign exchange account policies to introduce specialized banking services for Russia. While reducing transaction costs, it has also promoted business processing and development speed; Suifenhe District and Heihe District use their own loan business advantages to promote the development of the economic quality of the area. Suifenhe District has promoted and applied a series of loan businesses such as railway warehouse order pledge loans. Heihe District has launched "free trade E-loan", a loan for high-quality enterprises. Through a series of loan policies, the registered capital of Heihe District has exceeded 8 billion yuan, and Huawei and other high-quality large-scale private business entities and oil enterprises settled in the area.

3.2. Coordinated Industrial Development

According to the respective advantages of the three major regions, Heilongjiang takes forward the strengths and avoids the shortcomings, and carries the unique development positioning. It has formed a differentiated industrial pattern and its own strategy of coordinated development.

Harbin area has unique advantages in high-tech, information technology, new materials and ice and snow tourist attractions industry. There are national institutions of higher learning and other scientific research institutes like Harbin University of Technology in the area. Suifenhe District has made remarkable achievements in biomedicine, cross-border timber sales, etc. Through trade with Russia, Suifenhe District has rapidly developed the import and processing of traditional Chinese

medicinal materials in its area. The Heihe area pays more attention to trade and vigorously develops the import and processing of Russian electricity and cross-border timber import and export.

3.3. Green and Sustainable Development

As a key grain-producing region and agricultural base in China, the Heilongjiang Free Trade Zone has placed sustainable agricultural development at its core.

On one hand, the FTZ actively promotes a appropriate scale of agricultural operations. By precision planting, smart agriculture and other technological means, it reduces pesticide usage, achieving an intensive and green transformation of agricultural production. Concurrently, the zone is advancing the integrated and modernized development of crop and livestock industries. This involves strengthening technical guidance, fostering innovative models, and promoting the research, development, and application of organic fertilizers. These measures not only mitigate soil and water pollution stemming from chemical fertilizers but also enhance the safety and quality of agricultural products at their source.

3.4. Open Development of Trade

The advantage of openness and cooperation in the Heilongjiang FTZ lies in its unique geographical location and unique positioning given by the national strategy.

More importantly, the long-standing foundation of trade cooperation between China and Russia and the complementarity of industries provide broad space and solid support for the open cooperation between the Heilongjiang FTZ and Russia. The industrial gradient structure and supply and demand of China and Russia are highly complementary in energy sharing, agricultural import and export, high-tech and other fields, forming a good cooperation pattern of "Russian resource endowment + Chinese market channel + intelligent platform carrier". Coupled with the normalization mechanism of trade exchanges and the atmosphere of mutual trust in cooperation between the two sides for many years, the institutional cost of cross-border trade has been reduced.

3.5. Shared Development of Achievements

The development priorities of each district in Heilongjiang vary, yet the coordinated advancement across the three major districts has yielded mutually beneficial outcomes, further unleashing the developmental vitality of each area.

The Harbin district leveraged the oversight capabilities of the internet to reform the pharmaceutical distribution mechanism in the Suifenhe district. Thanks to the driving role of the association, it ensures the safety and compliance of drug distribution. Lending services in the Suifenhe and Heihe areas have also attracted many strong private enterprises and even foreign-funded companies in the Harbin area. Meanwhile, through innovative management approaches, the Suifenhe-Heihe area has developed into a smart region. This has not only enabled comprehensive monitoring of cross-border trade, but also solved problems such as disorderly transactions and limited scale, thereby greatly improving customs clearance efficiency.

4. Measurement of the High-quality Development Level of the Heilongjiang Free Trade Zone

On the basis of existing research, this article selects five first-level indicators and 20 second-level indicators of "innovation, coordination, green, openness and sharing" in Heilongjiang Province from 2009 to 2024 to evaluate the development level of Heilongjiang FTZ.

4.1. Selection of Indicators

This study adapts to the specific context of the Heilongjiang FTZ by adopting the primary indicators utilized by the aforementioned scholars. Furthermore, it selects appropriate secondary indicators that effectively reflect high-quality development performance to construct the specific indicator system for this research, as detailed in Table 1.

Table 1: Evaluation system

Goal system	First-level Indicator	Second-level Indicator
high-quality development of the Heilongjiang Free Trade Zone	innovation	hcl tech RD patent
	green	forest water green cover
	coordination	indus piGDP siGDP tiGDP
	openness	eiport open fdie fdic
	sharing	ubn income ins allow

4.2. Data Sources

This paper draws on data from the *Heilongjiang Statistical Yearbook*, *China Environmental Statistical Yearbook*, *China Urban Construction Statistical Yearbook*, the official website and internal databases of the China (Heilongjiang) Pilot Free Trade Zone, Ministry of Commerce platforms, the Wind database, and other relevant departmental sources. Refering to common practices in existing Principal Component Analysis (PCA), which mainly utilize data spanning 10 to 20 years. This paper selects a 16-year period from 2009 to 2024 as the foundational dataset to ensure analytical precision. The few missing values encountered were addressed using linear interpolation and regression imputation methods.

4.3. Model Selection and Calculation

4.3.1 Model Selection

Bracais decomposed the principal element into "main coordinates" for the first time in 1846, and Hotlin expanded the model, that is, using a few principal components to describe the intrinsic connection between multiple variables. Among them, the most typical method is to take the variance of the evaluation index as the evaluation indicator, and the greater the variance, the more it means that the evaluation index contains a rich amount of information. If the first principal component cannot fully reflect the information of the original data, the second linear combination can be considered, and so on, which constitutes the 3rd, 4th,...n and other main Ingredients. The formula is as follows:

$Fp = \alpha_{1i}X_1 + \alpha_{2i}X_2 + \ldots + \alpha_{ni}X_n$, where $\alpha_{ij} = \theta_j / \sqrt{\omega_i}$ denotes the weight of the variable in the principal component, θ_j represents the coefficient corresponding to the variable in the component matrix, and $\sqrt{\omega_i}$ is the square root of the eigenvalue associated with the i-th principal component.

4.3.2 Principal Component Analysis Method Calculation

First, Principal Component Analysis (PCA) requires the dimensionless processing of relevant data for Heilongjiang Province using Stata. Standardization methods for rendering data dimensionless include mean normalization, min-max scaling, range scaling, and standard deviation scaling. This study employs the standardization method. The data were imported into Stata software for statistical testing, as shown in Table 2.

Table 2: Descriptive statistics

Variable	Obs	Mean	Std. dev.	Min	Max
hcl	16	.023125	.0045198	.0185	.0311
tech	16	9.2625	2.828869	4.8	12.2
RD	16	3714.188	557.0383	2631	4343
patent	16	5506.125	3657.182	1532	12149
forest	16	1981.607	13.56195	1962.13	1990.46
water	16	13408.38	12440.5	112	45333
green	16	7.24875	.367802	6.42	7.76
cover	16	36.5625	1.812503	33.6	41.1
indus	16	.3261398	.0946223	.229024	.480707
piGDP	16	.0136049	.0180105	-.019831	.04859
siGDP	16	.0035717	.0416103	-.077686	.092702
tiGDP	16	.0380443	.0158836	.001285	.066224
eiport	16	302.9544	96.71036	162.3	438.9
open	16	.0246437	.0074266	.0139	.0388
fdie	16	5235	624.5757	4149	6278
fdic	16	62036.06	70840.2	10900	187316
ubn	16	.6159875	.0431098	.5549	.6784
income	15	37583.93	12080.38	17773	56248
ins	16	20997.44	595.8212	20283	22073
allow	16	203.7438	64.34856	127.6	285.7

When performing the KMO test and Bartlett's test of sphericity on sample data, a higher KMO value indicates stronger correlations among variables, suggesting greater suitability for principal component analysis. A KMO value below 0.5 generally indicates that the data are unsuitable for this method. Meanwhile, a significance level of less than 0.005 in Bartlett's test suggests that the correlation matrix is not an identity matrix, satisfying the sphericity assumption and thus supporting the use of factor or component analysis.

As shown in Table 3, the results obtained using Stata indicate a KMO value of 0.685 and a Bartlett's test significance level of 0.000. According to Kaiser's criteria, a KMO value above 0.6 is considered marginally acceptable for factor analysis, and the highly significant result of Bartlett's test reinforces that the variables are sufficiently correlated. Therefore, the dataset is deemed appropriate for subsequent principal component analysis.

Table 3: KMO and Bartlett test of sphericity

KMO and Bartlett test of sphericity		
KMO		0.685
Bartlett test of sphericity	Chi-square	430.303
	Degrees of freedom	91
	p-value	0.000

As can be seen from Table 4, there are three indicators for the contribution rate of principal component feature values from 2009 to 2024. Three principal components have been extracted, and the total contribution rate is all above 90%.

Table 4: Total variance explanation table

Component	Eigenvalue	Difference	Proportion	Cumulative
Comp1	8.63475	5.5468	0.6168	0.6168
Comp2	3.08795	2.08152	0.2206	0.8373
Comp3	1.00643	.312454	0.0719	0.9092
Comp4	.693974	.381541	0.0496	0.9588
Comp5	.312433	.145972	0.0223	0.9811
Comp6	.166461	.110528	0.0119	0.9930
Comp7	.0559329	.0328957	0.0040	0.9970
Comp8	.0230372	.0126586	0.0016	0.9986
Comp9	.0103786	.00549869	0.0007	0.9994
Comp10	.00487991	.00318174	0.0003	0.9997
Comp11	.00169817	.000488071	0.0001	0.9999
Comp12	.00121009	.000624968	0.0001	0.9999
Comp13	.000585127	.000304712	0.0000	1.0000
Comp14	.000280415	.	0.0000	1.0000

Secondly, extract the principal components whose feature values are greater than 1 and whose cumulative variance contribution rate reaches 85%. From the total analysis of variance table 5, we can see that the cumulative contribution rates of components 1, 2, and 3 have already exceeded 0.9, and their eigenvalues are all greater than 1. This principal component is extracted.

Table 5: Component matrix

Variable	Comp1	Comp2	Comp3
hcl	0.3230	0.1551	0.0884
tech	-0.3230	-0.1497	0.0818
RD	-0.1475	0.4218	0.2433
patent	0.3300	0.1055	0.0570
cover	0.2678	0.2430	0.3962
indus	-0.3130	0.2020	-0.0068
siGDP	-0.0562	0.3702	-0.4022
open	-0.1610	0.4286	0.2641
fdie	0.0534	0.3628	-0.6784
fdic	0.2960	0.2437	-0.0169
ubn	0.3386	-0.0180	0.0286
income	0.3350	0.0092	0.1176
ins	-0.1840	0.3905	0.2059
allow	-0.3327	-0.0005	0.1302

4.3.3. Evaluation Result

Based on the 4.4.1 model formula and with the aid of the stata tool, the scores of the three principal components and the overall score can be calculated, as shown in Table 6:

Table 6: Principal component score table

	F1	F2	F3	score
2009	-3.703118	.0478864	-.8715671	-2.569495
2010	-3.880124	1.797063	-.9294047	-2.269745
2011	-3.688553	2.372117	-.1698522	-1.940192
2012	-3.01472	.6720966	.5068931	-1.842025
2013	-2.630474	.6621518	.8012677	-1.560487
2014	-2.031839	.2086313	1.019506	-1.247153
2015	-.7958267	-2.932662	1.219408	-1.155011
2016	-.3160366	-2.906701	.2529918	-.8996475
2017	.0484767	-2.080834	.3099292	-.4474787
2018	.878841	-2.034451	-.772037	.0415309
2019	1.549518	-1.432879	-.8964926	.6326352
2020	3.111943	-.2680039	-1.658618	1.914947
2021	2.986526	1.185644	-1.053747	2.230398
2022	3.370286	1.394144	-.6293976	2.574887
2023	3.731692	1.52185	1.23579	2.998549
2024	4.383409	1.793947	1.635331	3.538288

As illustrated in Table 6, the comprehensive scores reveal three distinct phases about Heilongjiang FTZ development. Basing on the calculated annual composite scores and rankings, the analysis of dynamic evolution trend as follows: the period from 2009 to 2013 denotes a stage of gradual accumulation, characterized by a steady increase in scores; from 2014 to 2018, it entered a phase of platform fluctuation, where growth slowed or exhibited volatility; and after the FTZ's establishment in 2019, scores demonstrated a phase of accelerated growth, indicating a significant policy-driven effect.

In terms of subdivision, the three main components represent the driving forces of different dimensions. First main component (F1): Table 5 indicates that the two factors, ubn and income, have the highest contribution rate. They represent the total amount, scale and basic strength of economic development, and are the basic plate of high-quality development. The second main component (F2): As can be seen from Table 5, the two factors RD and open have the highest contribution rate. They reflect the transformation of the driving force of economic growth from factor-driven to innovation-driven, and are the core engine of high-quality development. The third main component (F3): As above table shown that the contribution rate of the two factors cover and allow is significant. They portray the sustainability and social equity of development. By analyzing the changes in the scores of this three main components over the years, we can find the evolution of the driving mode of this: early development may mainly rely on F1 (scale expansion), and then the contribution of F2 (innovation-driven) continues to increase, and F3 (green sharing) is increasingly becoming a new growth point. This shows that it is constantly being optimized and upgraded. These factors capture the sustainability and social equity dimensions of development.

By annual variations in the scores of the three principal components, analysis reveals the development of Heilongjiang FTZ. Early development may mainly rely on F1 (scale expansion), followed by a continuous increase in the contribution of F2 (innovation-driven). Meanwhile, F3 (green and shared development) is increasingly emerging as a new growth point. This pattern indicates a continuous optimization and upgrading of the development model in the Heilongjiang FTZ.

5. Conclusions and Suggestions

5.1. Conclusions

Based on the comprehensive analysis of the three main components, this article derives those following conclusions:

First, great development achievements have been built: the high-quality development levels have achieved leapfrog growth because of the FTZ advance, with the comprehensive score continues to rise. Second, optimization of the drive structure: the development momentum has changed from a single-scale drive to a multi-wheel drive mode of "scale base + innovation efficiency + green sharing", but there is still room for improved synergy between the three. Third, the basic shortcomings are obvious: the contribution of urban staff to scientific research. Technical services are still negative in the first two main components, which indicates the potential risk of the movement of scientific and technological personnel.

5.2. Suggestions

5.2.1. Lay Solid Foundations for Development, Stabilize the Scale and Support the Foundation

Purposefully attract the collection of high-quality capital elements, and at the same time consolidate the foundation of the development of various regions. It is vital to deepen the characteristic development positioning of the three major areas. The Harbin Area should take advantage of scientific and educational resources and industrial clusters. Focus on building a scientific research base for cooperation with Russia and a hub for high-end industries. The Heihe Area should capitalize on its status as a border port to play its functions. The Suifenhe Area should concentrate on constructing land-sea multimodal transport corridors, establishing a cross-border trade hub.

5.2.2. Initiating the Engine of Innovation and Activating the Dual Power of Innovation and Efficiency

The government should pay attention to innovation and increase investment in R&D funding. Establishing an investment mechanism in scientific research and optimising the construction of the system. Many universities and research institutions are concentrated in Harbin. This industry and school cluster provide a solid foundation for innovation. To use this function, you must use a dedicated platform. Cooperation must be established between industry, colleges and research. Meanwhile, the critical role of human capital must be acknowledged. By integrating the resources of various universities, carrying out specific talent training around the needs of the leading industries in the area, these cultivate skills and applied talents suitable for the development needs of these leading enterprises. On the other hand, the government should also introduce more attractive talent introduction policies, mainly for overseas high-end technical talents, improve talent evaluation mechanisms, curb the outflow of local talent, and provide a stable and sustainable talent pipeline for the area’s economic development.

5.2.3. Deepen Coordinated Development and Realize the Integration of Green and Shared Values

The green transition of industries across areas is essential. The focus of cultivation should be placed on strategic environmental sectors. A novel set of entry standards and evaluation systems for

green projects should be established, high-pollution enterprises to enhance the level of green development in the areas. Furthermore, the framework for social fairness and sharing must be sound, aiming for common prosperity by optimizing income distribution and redistribution mechanisms, and improve the wage growth mechanism. Furthermore, it is vital to enhancing the rational allocation of public service resources among areas, improving various social security measures, and benefiting a broader population.

5.2.4. Develop Characteristic Industrial Carriers in Each Area and Promote Industrial Structure Upgrading

First, a new model for industrial cluster development should be constructed. Based on the resource endowments and development foundations of the three areas, characteristic industrial parks should be scientifically planned and developed. By leveraging the advantages of industrial agglomeration and spatial layout, local stock resources can be activated, and the R&D and production functions of each park optimized. Simultaneously, the government's planning and guidance functions should be strengthened to clarify each area's development direction, avoid homogeneous and invalid competition among areas and promote complementary functions. Second, the layout of the enterprise structure should be optimized. Addressing issues such as the small scale of some enterprises and the lagging development of the secondary industry. According to this phenomenon, the government should promote linkages between Heihe's industries and Harbin's high-tech R&D sectors. Meanwhile, the government should introduce the advanced technology and resource elements, and facilitate the integrated and coordinated development of enterprises.

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