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Evaluation of the Development Vitality of New Quality Productive Forces in Beijing-Tianjin-Hebei Region Based on Game Theory-TOPSIS Method

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Abstract: This paper employs a Game Theory-based Weighting and Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method to comprehensively evaluate the development vitality of new quality productive forces in Beijing, Tianjin, and Hebei. By integrating the Analytic Hierarchy Process (AHP) and Entropy Method to determine weights, a scientific evaluation index system is constructed, incorporating both expert opinions and objective data. The evaluation results indicate that Beijing excels in technological innovation and efficiency, Tianjin performs well in green development, while Hebei requires enhancement in industrial transformation and upgrading. Encompassing multiple dimensions such as technological innovation, intellectual resources, green development, production efficiency, and industrial transformation and upgrading, the assessment further validates the effectiveness of the evaluation methodology through case study analysis. The Game Theory-based Weighting approach effectively combines subjective and objective weights, enhancing the scientific rigor and accuracy of the evaluation. The results provide a decision-making basis for optimizing industrial structures, promoting regional collaboration, advancing green and low-carbon development, and improving social well-being in the Beijing-Tianjin-Hebei region. In conclusion, the proposed Game Theory-based Weighting and TOPSIS evaluation model serves as a powerful tool for assessing the development vitality of new quality productive forces in Beijing, Tianjin, and Hebei. It holds significant implications for driving regional high-quality development, achieving economic growth with high quality, and fostering sustainable social development.

Keywords: New Quality Productive Forces; Game Theory Weighting; TOPSIS Method; Development Vitality Assessment; Beijing-Tianjin-Hebei Region

1. Introduction

During his inspection in Heilongjiang in September 2023, President Xi Jinping first introduced the concept of new quality productive forces. new quality productive forces encompasses a multitude of sectors, including high-tech industries, modern service industries, green economy industries, digital economy industries, and intelligent manufacturing industries. These industries, driven and propelled by technological innovation, continuously spawn new industries, new models, and new growth engines, thereby injecting significant momentum into the high-quality development of the economy and society. The core element of new quality productive forces is technological innovation, which can foster new industries, new models, and new growth engines. To cultivate and develop new growth engines for new quality productive forces, it is essential to strengthen technological innovation, particularly in the areas of original and disruptive technological advancements, and accelerate the process of achieving high-level scientific and technological self-reliance.

The characteristics of new quality productive forces encompass efficiency, precision, digitization, intelligence, and greenness. It significantly enhances production efficiency and quality while reducing costs and resource consumption, thereby generating more economic benefits for enterprises and society. Additionally, new quality productive forces emphasizes environmental protection and sustainable development, minimizing resource consumption and pollution emissions during the production process.

Evaluating the vitality of new quality productive forces development is crucial for promoting high-quality economic and social development. Through evaluation, we can better understand the current state and development trends of productivity, identify development bottlenecks, stimulate innovation vitality, optimize resource allocation, and promote sustainable development to address changes and challenges in the domestic and international environments.

Based on this foundation, assessing the vitality of new quality productive forces development in Beijing-Tianjin-Hebei (BTH) region will directly impact future economic development directions. It will help optimize industrial structures, promote coordinated regional development, drive green and low-carbon development, and improve social livelihoods. the evaluation results will provide important decision-making references for the three regions, facilitating the achievement of high-quality economic growth and sustainable social development.

Against this backdrop, it is of great significance to establish a scientific and comprehensive evaluation system. Based on a comprehensive consideration of the multi-dimensional characteristics of new quality productive forces, this paper innovatively introduces a weighting method based on game theory and the TOPSIS evaluation model, aiming to conduct a comprehensive and systematic assessment of the development vitality of new quality productive forces in Beijing, Tianjin, and Hebei through a combination of qualitative and quantitative methods. the TOPSIS method, known as the Technique for Order Preference by Similarity to an Ideal Solution, is widely used in various fields due to its ability to objectively reflect the proximity of evaluation objects to the ideal solution and its high flexibility and effectiveness in dealing with multi-attribute decision-making problems.

Next, we will elaborate on the application of the weighting method based on game theory in determining the weights of evaluation indicators, as well as the specific implementation steps of the TOPSIS method and its practical application in evaluating the development vitality of new quality productive forces. the establishment of this evaluation system not only provides a scientific assessment tool for the development of new quality productive forces but also offers important decision-making references for the optimization and adjustment of regional economies, collaborative development, and green and low-carbon development.

2. Preliminaries

2.1 The Game Weighting Method is Used to Determine the Index Weight

1) the analytic hierarchy process was used to determine the subjective weight of the index

Step 1: Obtain the judgment matrix A between criterion i and j

Let A be the judgment matrix obtained after pairwise comparison between criteria, where n represents the number of criteria. When criterion i is equally important, slightly more important, notably more important, strongly more important, and extremely more important than criterion j, the corresponding values are 1, 3, 5, 7, 9, respectively. the median values between the two adjacent judgments mentioned above are represented by 2, 4, 6, 8, resulting in a total of 9 scales. Therefore, $A = (a_{ij})_{n\times n}$.

Step 2: Calculate the subjective weight of the i-th indicator

Using the arithmetic mean method to obtain the weight: a. Normalize the judgment matrix by columns. b. Sum up the normalized columns. c. Divide each element in the resulting vector by n to obtain the weight vector.

$$\omega_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n} a_{ij}}, (i = 1,2,\cdots,n)$$

Use the geometric average method to find the weight: a. Multiply the elements of a by rows to get A new column vector b. Raise each component of the new vector to the n-th power c. Normalize the column vector to get the weight vector.

$$\omega_i = \frac{1}{n}\sum_{j=1}^{n}\frac{a_{ij}}{\sum_{k=1}^{n} a_{ij}}, (i = 1,2,\cdots,n)$$

Using the Eigenvalue Method to Determine Weights: Under the condition that the

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consistency of the judgment matrix is accepted, a. calculate the maximum eigenvalue of the matrix A and its corresponding eigenvector; b. normalize the obtained eigenvector to obtain the weight vector.

2) Determining Objective Weights of Indicators Using the Entropy Method

Step 1: Suppose there are n evaluation objects and m evaluation indicators, resulting in a non-negative matrix Z as follows:

$$\begin{bmatrix} Z_{11} & \cdots & Z_{1m} \\ \vdots & \ddots & \vdots \\ Z_{n1} & \cdots & Z_{nm} \end{bmatrix}$$

Step 2: Calculate the proportion of the i sample in the j index

Calculate the introduction matrix P, where the formula for each element P_{ij} of P is as follows:

$$P_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{n} Z_{ij}} \; and \sum_{i=1}^{n} P_{ij} = 1$$

Step 3: Calculate the information entropy of each indicator, calculate the information utility value, and normalize the entropy weight of each indicator

For the j-th index, its information entropy is calculated as follows:

$$e_j = -\frac{1}{lnn}\sum_{i=1}^{n} p_{ij} ln(p_{ij}), (j = 1,2,\cdots,m)$$

The definition of information utility value: $d_j = 1 - e_j$ the greater the information utility value, the more information it corresponds to.

By normalizing the information utility value, we can get the entropy weight of each indicator:

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j}, (j = 1,2,\cdots,m)$$

3)Using game theory to determine the combined weight of indicators

Step 1: Set the subjective weight vector of the index ω_1 obtained based on analytic hierarchy process as and the objective weight vector of the index ω_2 obtained based on entropy method as, then any linear combination of subjective and objective weight vectors can be established as follows:

$$\omega = \sum_{l=1}^{2} \alpha_l \omega_l^T = \alpha_1 \omega_1^T + \alpha_2 \omega_2^T$$

Where, α_l is the linear combination coefficient and ω is the set of possible weight vectors.

Step 2: Based on game theory, the following game model is constructed with the goal of minimizing the deviation between ω and ω_l:

$$min\left\| \sum_{l=1}^{2} \alpha_l \omega_l^T - \omega_p \right\|, p = 1,2$$

Step 3: In order to optimize the above game model, the following optimization conditions must be met:

$$\sum_{l=1}^{2} \alpha_l \omega_p^T = \omega_p \omega_p^T, p = 1,2$$

Step 4: According to the above optimization conditions, the linear combination coefficient (α_1, α_2) can be obtained and normalized.

$$\alpha_l^* = \frac{\alpha_l}{\sum_{l=1}^{2} \alpha_l}$$

Step 5: Substitute α_l^* into the linear combination formula to obtain the combined weight vector for the indicators.

$$\omega^* = \sum_{l=1}^{2} \alpha_l^* \omega_l^T = \alpha_1^* \omega_1^T + \alpha_2^* \omega_2^T$$

2.2 Using TOPSIS Method to Evaluate the Development Vitality of New Productivity

1)Suppose there are n evaluation objects and m evaluation indexes, the original decision matrix can be established as follows $A = (a_{ij})_{n\times n}$.

2)After standardizing A, the standardized matrix $K = (k_{ij})_{n\times m}$ can be obtained. Among them, the standardization formulas for benefit-type indicators and cost-type indicators are as follows:

$$k_{ij} = \frac{a_{ij}}{\sum_{i=1}^{n}(a_{ij})^2}; k_{ij} = \frac{\frac{1}{a_{ij}}}{\sqrt{\sum_{i=1}^{n}(\frac{1}{a_{ij}})^2}}$$

3) Calculate the weighted normalized matrix Z

$$Z = (z_{ij})_{n\times m} = (\omega_j^* \times k_{ij})_{n\times m}$$

4) Calculate the positive ideal solution Z^+ and negative ideal solution Z^- of the index

$$Z^+ = (Z_1^+, Z_2^+, \cdots, Z_m^+) = (max\{z_{11}, z_{21}, z_{n1}\}, max\{z_{12}, z_{22}, z_{n2}\}, \cdots, max\{z_{1m}, z_{2m}, z_{nm}\})$$

$$Z^- = (Z_1^-, Z_2^-, \cdots, Z_m^-) = (min\{z_{11}, z_{21}, z_{n1}\}, min\{z_{12}, z_{22}, z_{n2}\}, \cdots, min\{z_{1m}, z_{2m}, z_{nm}\})$$

5) Calculate the distance and relative proximity between the $i(i = 1, 2, \cdots, n)$ evaluation object and the maximum and minimum values

$$D_i^+ = \sqrt{\sum_{j=1}^{m}(Z_j^+ - z_{ij})^2}, D_i^- = \sqrt{\sum_{j=1}^{m}(Z_j^- - z_{ij})^2}$$

$$RC_i = \frac{D_i^-}{(D_i^- + D_i^+)}, i = 1,2,\cdots,n$$

6) Calculate and normalize the score of the $i(i = 1, 2, \cdots, n)$ object

$$S_i = \frac{D_i^-}{D_i^+ + D_i^-}, \widetilde{S_i} = \frac{S_i}{\sum_{i=1}^{n} S_i}$$

Sort $\widetilde{S_i}$ the larger the value of $\widetilde{S_i}$, the stronger the vitality of the new productive forces; the smaller the value of $\widetilde{S_i}$, the weaker the vitality of the new productive forces.

Establish a new quality productive forces evaluation index system

1)It is assumed that the data we can obtain is accurate and can reflect the main characteristics of the new quality productive forces in Beijing-Tianjin-Hebei region.

2)It is assumed that the evaluation indicators we selected can comprehensively and accurately reflect the level of new quality productive forces in Beijing-Tianjin-Hebei region, ignoring the influence of some secondary factors on the evaluation results.

3)In the TOPSIS model, it is assumed that the standardization process of the decision matrix is reasonable, which can eliminate the dimensional differences between different indicators and make each indicator comparable in the evaluation.

To evaluate the development vitality of new quality productive forces, it is necessary to establish a comprehensive evaluation system structure. Based on the research of relevant literature and taking into account the characteristics of economic development, an evaluation system for assessing the development vitality of new quality productive forces has been constructed, encompassing five distinct dimensions. technological innovation, intellectual resources, green development, production efficiency, and industrial transformation and upgrading, encompassing a total of 14 indicators. This system is established adhering to the principles of scientificity, comprehensiveness, comparability, accessibility, and the integration of absolute and relative numbers. the specific content is shown in Table 1

Table 1. New Quality Productive Forces Development Vitality Evaluation Index System

Criterion layer	Index level	Indicator interpretation	Index unit	Index attribute
Technological Innovation A	R&D investment a1	R&D expenditure/GDP	%	Positive
	Patent grant a2	Number of patents granted in the whole society	Piece	Positive
	Research income a3	Added value of scientific research and technical services	Hundred million yuan	Positive
Intellectual resources B	Talent ratio b1	The proportion of the population with college degree or above in the working population	%	Positive
	Research input b2	Research and development expenditure per researcher	Ten thousand yuan/person	Positive
	Research institution b3	Number of national and local research institutes	Unit	Positive
	Talent input b4	R&D personal equivalent to full-time equivalent	Ten thousand people/year	Positive
Green development C	Exhaust emission c1	Sum of sulfur dioxide and nitrogen oxide emissions/hundred-million-yuan GDP	Tons/hundred million yuan	Negative
	Waste water discharge c2	Waste water discharge/hundred-million-yuan GDP	Ten thousand tons/ hundred million yuan	Negative
	Solid waste discharge c3	Solid waste/hundred-million-yuan GDP	Ten thousand tons/ hundred million yuan	Negative
Production efficiency D	Input-output ratio d1	Industrial added value/fixed asset investment in the secondary industry	%	Positive
	Labor productivity d2	High-tech industry employment output value/high-tech industry number	Ten thousand yuan/person	Positive
Industry transformation and upgrading E	The proportion of high-tech industry e1	High-tech business income/GDP	%	Positive
	Internet penetration e2	The proportion of Internet users to the total resident population	%	Positive

3 TOPSIS models

3.1 Data Preparation

At present, in order to evaluate the development vitality of new quality productive forces in the Beijing-Tianjin-Hebei region (Beijing, Tianjin and Hebei), it is necessary to evaluate the development vitality of new quality productive forces in the three regions from the dimensions of technological innovation, intellectual resources, green development, production efficiency and industrial transformation and upgrading. After data collection and processing, the evaluation index value of the development vitality of new quality productive forces in the three places can be obtained, as shown in Table 2.

Table 2. Basic Information of Evaluation Indicators for the Development Vitality of Beijing-Tianjin-Hebei New Quality Productive Forces

Criterion	Index	Vitality of new quality productive forces Development in 2022		
		Beijing	**Tianjin**	**Hebei**
Technological Innovation	R&D investment	6.83	3.49	2.00
	Patent grant	202722.00	71545.00	115311.0
	Research income	3465.00	585.00	732.00
Intellectual resources	Talent ratio	0.93	0.69	0.32
	Research input	52.00	27.20	67.30
	Research institution	405.00	165.00	73.00
	Talent input	373235.00	103499.00	158712.8
Green development	Exhaust emission	1.81	5.82	21.26
	Wastewater discharge	5.50	3.27	3.46
	Solid waste discharge	41.10	0.12	0.88
Production efficiency	Input-output ratio	4.97	1.27	0.76
	Labor productivity	162.23	207.50	56.38
Industry transformation and upgrading	The proportion of high-tech industry	0.07	0.05	0.02
	Internet penetration	0.4	0.46	0.4

3.2 Weight Definition

1) Using analytic hierarchy process, subjective weight can be obtained. According to expert opinions, the judgment matrix is obtained, as shown in the following table.

Table 3. New Quality Productive Forces Development Vitality Judgment Matrix

	a1	a2	a3	b1	b2	b3	b4	c1	c2	c3	d1	d2	e1	e2
a1	1	5	2	2	3	1	2	2	3	3	3	1	1	7
a2	1/5	1	1	1/2	2	1/5	1/2	1	1/2	1/2	1/2	1/2	1/3	2
a3	1/2	1	1	1	2	1/2	1/2	1/2	1/2	1/2	1/2	1	1	2
b1	1/2	2	1	1	3	3	1	2	2	3	3	3	2	1/2
b2	1/3	1/2	1/2	2	1	1/5	1	1/5	1/3	1/3	1/3	1/2	1/2	5
b3	1	5	2	1/3	5	1	5	2	2	2	2	2	2	2
b4	1/2	2	2	1	1	1/5	1	2	1/2	1/2	1/2	1	1	5
c1	1/2	1	2	1/2	5	1/2	1/2	1	1/2	1/2	1/2	1	1	2
c2	1/3	2	2	1/2	3	1/2	2	2	1	1	1	1/2	1/2	2
c3	1/3	2	2	1/3	3	1/2	2	2	1	1	1	1/2	1/2	2
d1	1/3	2	2	1/3	3	1/2	2	2	1	1	1	1/2	1/2	2
d2	1	2	1	1/2	2	1/2	1	1	2	2	2	1	1	2
e1	1	3	1	1/2	2	1/2	1	1	2	2	2	1	1	3
e2	1/7	1/2	1/2	1/2	1/5	1/2	1/5	1/2	1/2	1/2	1/2	1/2	1/3	1

The weights are calculated by arithmetic average method, geometric average method and eigenvalue method respectively, and the results are as follows as Table 4.

Table 4. New Quality Productive Forces Development Vitality Index Weight

Indicator	Arithmetic Method	Geometric Method	Eigenvalue Method
R&D investment	0.1347	0.1364	0.1355
Patent grant	0.0375	0.0382	0.0373
Research income	0.0517	0.0495	0.0505
Talent ratio	0.0272	0.0266	0.0270
Research input	0.1362	0.1420	0.1364
Research institbution	0.0563	0.0538	0.0562
Talent input	0.0648	0.0593	0.0631
Exhaust emission	0.0642	0.0647	0.0646
Waste water discharge	0.0642	0.0647	0.0646

Solid waste discharge	0.0642	0.0647	0.0646
Input-output ratio	0.0765	0.0773	0.0769
Labor productivity	0.0790	0.0796	0.0794
The proportion of high-tech industry	0.1148	0.1145	0.1156
Internet penetration	0.0287	0.0287	0.0283

2) the objective weights of indicators can be obtained by using the entropy method, as shown in column 3 of Table 5.

3) the combined weights of indicators can be obtained by using the game weighting method, as shown in Column 5 of Table 5.

Table 5. Calculation Results of Each Indicator's Weight

Criterion	Index	Objective Weight	Subjective Weight	Game Weight	Total
Technological Innovation	R&D investment	0.0429	0.1355	0.0781	0.2026
	Patent grant	0.0314	0.0373	0.0336	
	Research income	0.1156	0.0505	0.0909	
Intellectual resources	Talent ratio	0.0293	0.0270	0.0284	0.2187
	Research input	0.0220	0.1364	0.0655	
	Research institbution	0.0762	0.0562	0.0686	
	Talent input	0.0519	0.0631	0.0562	
Green development	Exhaust emission	0.1485	0.0646	0.1166	0.3471
	Waste water discharge	0.1465	0.0646	0.1154	
	Solid waste discharge	0.1461	0.0646	0.1151	
Production efficiency	Input-output ratio	0.1098	0.0769	0.0973	0.1527
	Labor productivity	0.0407	0.0794	0.0554	
Industry transformation and upgrading	The proportion of high-tech industry	0.0383	0.1156	0.0677	0.0789
	Internet penetration	0.0008	0.0283	0.0112	

3.3 Weight Analysis

According to Table 5, there is a large deviation between the subjective and objective weights of most indicators. Among them, the deviation degree of subjective and objective weights of research investment and R&D investment is the largest. the reasons are as follows: a) from the perspective of experts, both product technology research and development and scientific research are the core driving forces to promote technological innovation, achieve technological breakthroughs and industrial upgrading. They can continuously generate new productive forces, enhance the competitiveness of countries and enterprises, and are crucial to the development vitality of new productive forces. b) from the perspective of objective data, the range of research investment values in Beijing-Tianjin-Hebei region is 40.10, and the dispersion coefficient is 0.41%. the range of R&D investment is 4.38, and the dispersion coefficient is 0.60%. Therefore, these two indicators are assigned with less weight. When a certain index value of Beijing-Tianjin-Hebei is relatively close, that is, the dispersion coefficient is small, the objective weight is relatively small, while the subjective weight is assigned according to the importance of the index, so the deviation between subjective and objective weights will occur. the game combination weighting method proposed in this paper can weaken the deviation between the game combination weight and the subjective and objective weights, so as to overcome the one sidedness brought by the single subjective or objective weighting method, and effectively make up for the deficiency of the commonly used combination weighting method.

Figure 1 shows the distribution of the three weights. From the perspective of objective weighting, the importance of criteria is ranked as green development>technological innovation>intellectual resources>production efficiency>industrial transformation and upgrading; from the perspective of subjective weighting, the importance of criteria is intellectual resources>technological innovation>green development>production efficiency>industrial transformation and upgrading; from the perspective of game combination weighting, the importance of criteria is green development> intellectual resources>technological innovation>production efficiency>industrial transformation and upgrading. the game combination weighting method can improve the distinction of importance among criteria and overcome the one-sidedness of single weighting, so as to make the evaluation results more scientific and reasonable.

From the perspective of game portfolio weight, currently, when evaluating the development vitality of new quality productive forces, the three indicators of waste gas emission, waste water emission and solid waste emission in green development are given priority, while the three indicators of Internet penetration rate in industrial transformation and upgrading, the proportion of talents in intellectual resources and patent authorization in technological innovation are relatively less considered. That is, green development is the main assessment basis for the development vitality of new quality productive forces.

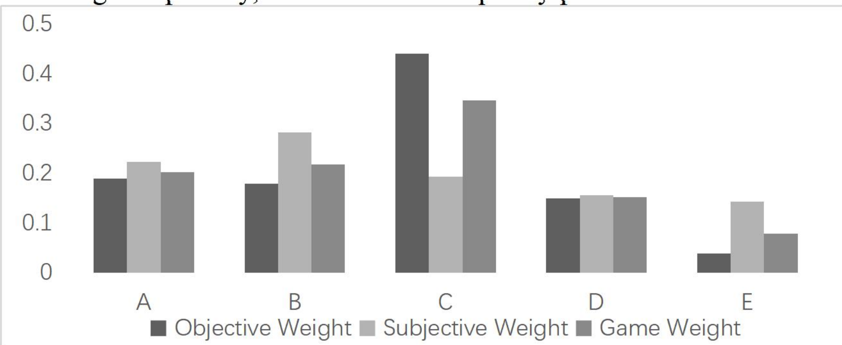

Figure 1. Different Aspects of Objective, Subjective and Game Weight

4. Refine Results

4.1 Calculation Results based on Game Empowerment -TOPSIS Evaluation Model

The calculation results of the game-weighted TOPSIS evaluation model are shown in Table 6. It can be seen from Table 6 that under the criteria of technological innovation, Beijing has the highest development vitality of new quality productive forces, while Tianjin has the lowest; Under the criterion of intellectual resources, Beijing has the highest development vigor while Tianjin has the lowest; Under the green development criterion, Tianjin has the highest development vigor while Beijing has the lowest; Under the criterion of production efficiency, Beijing has the highest development vigor while Hebei has the lowest; Under the criteria of industrial transformation and upgrading, Beijing has the highest development vitality while Hebei has the lowest. In order to obtain the development vitality of the new quality productive forces in the three places of Beijing, Tianjin and Hebei, we should judge according to the comprehensive evaluation value, Beijing's comprehensive evaluation value is the highest, so we can get the conclusion that Beijing's new quality productive forces development vitality is the highest.

Table 6 the Calculation Results of the Game Weighted -TOPSIS Model

Criterion	Vitality of new quality productive forces Development		
	Beijing	Tianjin	Hebei
Technological Innovation	0.5385	0.1817	0.1882
Intellectual resources	0.6915	0.3277	0.3420
Green development	0.2718	0.7231	0.4774
Production efficiency	0.2383	0.1550	0.0543
Industry transformation and upgrading	0.1058	0.0944	0.0612
Total	0.4121	0.3337	0.2542

4.2 Comparison of Three Evaluation Models

According to different ways of weighting, general TOPSIS evaluation models include subjective weighting -TOPSIS evaluation model and objective weighting -TOPSIS evaluation model, etc. According to the above data and evaluation model principles, the optimal solution set of various evaluation models can be obtained, as shown in Table 7.

Table 7. Comparison of Calculation Results of Three Models

Region	Subjective weight-TOPSIS	Objective weight-TOPSIS	Game weight-TOPSIS
Beijing	0.4473	0.3966	0.4121
Tianjin	0.3158	0.3429	0.3337
Hebei	0.2369	0.2605	0.2542
Range	0.2104	0.1361	0.1579
Variable coefficient	0.3189	0.2057	0.2369
Rank	Beijing>Tianjin>Hebei		

It can be seen from Table 7 that:

a) According to the subjective weight-TOPSIS model, objective weight-TOPSIS model and game weigh-TOPSIS model, the ranking of the development vitality of the new quality productive forces in the three places can be Beijing>Tianjin>Hebei. Although the ranking results of the three evaluation models are the same, there are still differences in comprehensive scores and other aspects. the reason lies in the difference in index weights. the weight of each index obtained by the game weight method is between the main weight and the objective weight, which can not only consider the preferences of experts, but also take into account the information value of objective data, so as to make the evaluation results more objective and fairer, but also reduce the influence of some extreme main and objective weight values on the evaluation results. In this paper, the weighting coefficient of the subjective game is 0.37999 and that of the objective game is 0.62001, which makes the weight of the game combination biased to the subjective weight.

b) the range of comprehensive evaluation value of subjective weight-TOPSIS model, objective weight-TOPSIS model and game weight-TOPSIS model is 0.2104, 0.1361 and 0.1579, and the coefficient of variation is 0.3189, 0.2057 and 0.2369, respectively. It is easy to know that the greater the range and coefficient of variation, the higher the discrimination level of comprehensive evaluation value, the greater the degree of dispersion, the easier to get the new quality productive forces development of the most vigorous areas. Obviously, the range and coefficient of variation of the comprehensive evaluation value obtained by the subjective weight-TOPSIS model are larger than those of the other two models. However, due to its subjectivity, the distribution of the comprehensive evaluation value obtained by the game weight-TOPSIS model is more reasonable and even, which is conducive to obtaining more accurate development vitality of the new quality productive forces in the three places.

5. Conclusions and Policy suggestions

In order to better understand the development vitality of new quality productive forces in the three regions of Beijing, Tianjin and Hebei (Beijing, Tianjin and Hebei), the following figure shows the change trend of new quality productive forces development vitality in the three regions from 2015 to 2022. During this period, the development vigor index of new quality productive forces in Hebei showed an overall upward trend. the development vitality of new quality productive forces in Beijing showed a slightly declining trend during the investigation period, but the overall development vitality was still higher than that of Tianjin and Hebei. the vitality of Tianjin is lower than that of Beijing but always higher than that of Hebei, showing a downward trend and then an upward trend.

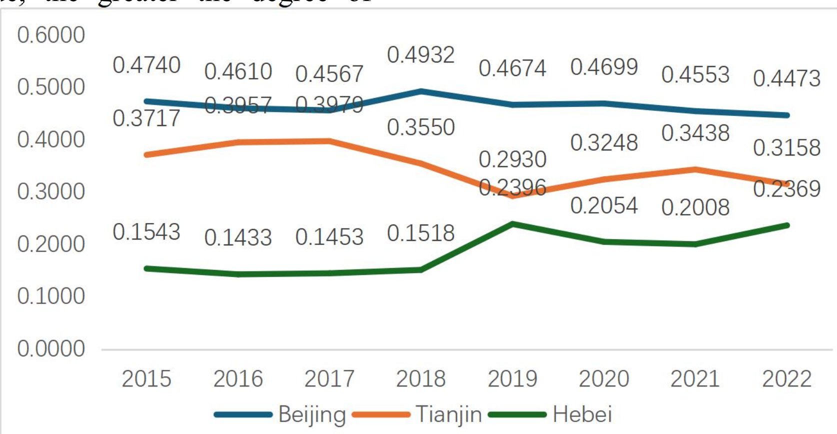

Figure 2 Change Trend of the Development Vitality of New Quality Productive Forces in Beijing-Tianjin-Hebei

As the pivotal driving force behind the transformation and upgrading of the modern economic system, new quality productive forces is characterized by its relentless pursuit of high technology, high efficiency, and high quality. This process profoundly embodies a fundamental transcendence and reshaping of traditional productivity models, aligning closely with the transformation of productivity quality advocated by the new era's development concepts. At the heart of this evolution lies the continuous leadership of advanced scientific and technological innovations, particularly the extensive penetration and application of digital, intelligent, and green technologies. These innovations have not only reshaped the forms of production tools and labor materials but also spurred groundbreaking advancements in cutting-edge fields such as artificial intelligence, quantum computing, and brain-computer interfaces.

Taking the Beijing-Tianjin-Hebei region as an example, this region, as a significant growth pole of China's economy, has achieved remarkable success in the development of new quality productive forces, providing an important window for observing China's path of development in this regard. Beijing, leveraging its abundant scientific research resources and higher education advantages, has become a cradle of technological innovation, effectively promoting the deep integration of modern service industries and high-tech industries. Tianjin, on the other hand, has constructed a modern industrial system centered on intelligent technology as its core competitiveness, achieving significant breakthroughs in areas such as information technology innovation and high-end equipment manufacturing. Hebei, for its part, leverages its own resource endowments to actively develop strategic emerging industries like new-generation information technology and high-end equipment manufacturing, forming a complementary and collaborative development pattern with Beijing and Tianjin, jointly showcasing the vibrant vitality and broad prospects of China's new quality productive forces development.

However, the development of new quality productive forces nationwide still faces issues of imbalance and inadequacy among regions. To address these challenges, we must draw upon the successful experience of regional coordinated development such as that in the Beijing-Tianjin-Hebei region, leveraging the spatial spillover effects of new quality productive forces to optimize and share innovation resources among regions, thereby driving balanced improvements in new quality productive forces nationwide and narrowing regional development disparities. For instance, the Guanzhong Plain urban agglomeration should focus on Xi'an, strengthening transportation infrastructure construction, enhancing regional interconnectivity, and relying on key high-tech industries such as aerospace, equipment manufacturing, and electronic information to build industry clusters with regional characteristics, thereby promoting the development of new quality productive forces. the Qianzhong urban agglomeration, centered on Guiyang, should continue to develop emerging industries such as big data and cloud computing, striving to become the "Digital Valley of China" while strengthening cooperation with ASEAN countries to leverage ecological advantages in developing eco-tourism and health industries, thereby advancing new quality productive forces. the Guangdong-Hong Kong-Macao Greater Bay Area should deepen cooperation in finance, technology, and industry, fostering an international financial and technological innovation center and a world-class urban agglomeration with global competitiveness. It should also strengthen regional integration, optimize industrial layouts, accelerate technological innovation, and jointly build a world-class urban agglomeration with global influence.

Moreover, talent, as the core element of new quality productive forces development, cannot be overlooked in terms of its balanced allocation and educational equity. Greater investments in educational resources in central and western regions should be made, leveraging policy preferences and financial support to enhance the quality of local higher education and scientific research, thereby attracting and retaining outstanding talents. Additionally, more flexible and diverse talent introduction policies should be implemented, providing comprehensive support and safeguards for strategic scientists and leading talents to ensure a solid foundation of talent and intellectual support for the development of new quality productive forces.

Finally, to further strengthen the supporting role of technological innovation in the development of new quality productive forces, we must continually optimize the innovation ecosystem and policy environment. Governments should simplify administrative approval procedures, lower market access thresholds, and provide more convenient services and support for the establishment and development of innovative enterprises. Simultaneously, a series of preferential policies such as tax reductions and exemptions and financial subsidies should be introduced to attract more innovation resources to concentrate in the field of new quality productive forces. Furthermore, the planning and construction of high-tech development zones and science and technology parks should be strengthened to provide enterprises with comprehensive innovation services and support, promoting the sustained, healthy development, and transformation and upgrading of new quality productive forces.

6. Summary

Based on the reference of relevant literature and the characteristics of the development vitality of new quality productive forces in different regions, this study first constructed an evaluation index system of the development vitality of new quality productive forces with 5 criteria and 14 indicators, determined the weights of each index by means of game empowerment method, and applied TOPSIS method to evaluate the development vitality of Beijing, Tianjin and Hebei. the results showed that, Intellectual resources are the main factors influencing the development vigor of new quality productive forces, and the development vigor of Beijing is higher than that of Tianjin and Hebei. At the same time, it also shows that the weight obtained by the game combination is different from the subjective weight and the objective weight. Under the comprehensive effect of the weighted coefficient of the main and objective game, it is more scientific and reasonable to evaluate the development vitality of the new quality productive forces. the game weight-TOPSIS evaluation model is simple and easy to operate, and the obtained comprehensive evaluation value is more evenly distributed and reasonable than the general TOPSIS evaluation model, and the difference between neighboring comprehensive evaluation values is more significant, which is more conducive to obtaining accurate results.

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