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Independent Innovation Capacity of Chinese High-Tech Industries Using CRITIC and TOPSIS Methods

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Abstract

Knowledge always constitutes the primary productive force for the social and economic development of the country, and consequently innovation has become a new development theme in most countries worldwide. Characterized by high profitability and high growth, Chinese high-tech industries show a rapid growth trend in size and effectiveness, which have been the supporting force and cornerstone for the national economy to promote the upgrading of products and industrial structures. In this study, a combination of Criteria Importance through Intercriteria Correlation (CRITIC) and Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method was proposed to evaluate the innovation capacity of high-tech industries. A total of 25 three-level evaluation indicators were established to construct a high-tech industry innovation capacity indication system. The CRITIC method was used to calculate the weight of each indicator, and the TOPSIS method was used to make comprehensive decisions on the high-tech industries of 31 provinces in China. Results show that the development trends of high-tech industries vary greatly in the 31 provinces of China. The top five indicators are the rate-of renovation and reformation projects completed and put into use; the amount of investment in renovation and reformation; the rate of projects completed and put into use; the gross value of production and operation output at current prices; and the expenditure of large and medium-sized high-tech enterprises on technology reformation. These indicators are the critical factors affecting the ranking of high-tech industries at the provincial level. Guangdong ranks first, followed by Jiangsu and Zhejiang, sequentially. The differences in economic and geographical factors initially result in the regional distribution imbalance of high-tech industries, typically "the eastern preceding over the middle, and the middle preceding over the western." Conclusions provide significantly valuable references in expanding the indication system for a comprehensive evaluation of the independent innovation capacity of high-tech enterprises, which also show valuable references in suggesting measures for the government and enterprises to improve the independent innovation capacity of high-tech enterprises.

Keywords: CRITIC method, TOPSIS method, High-tech industry, Innovation capacity, Evaluation

1. Introduction

Science and technology are developing rapidly in all countries worldwide, and the comprehensive competitiveness of high-tech industries is increasingly considered a decisive factor for developing a country's productive forces. The global technological competition of high-tech industries has been the focus of competition for comprehensive national strength, pushing the high-tech industry to the commanding elevation in a new round of international competition. Governments regard the development of high-tech industries and the realization of industrialization as strategic measures for the high-quality and long-term development of a country. In China, the large population, the lack of per capita resources, the dominant economic pattern of extensive development for a long period, and other bottlenecks of development led to a series of problems, such as large total energy consumption and large environmental ecology pressure. As the Chinese economy has entered the development stage of the "New Normal," traditional industries play a decreasing role in the overall national economy. Innovation in science and technology has become a new economic growth point and potential space in China. Therefore, the transformation of the economic development mode allows no delay in the sustainable and high-quality development of the Chinese economy. In such transformation, science and technology innovation is a critical element that must take up an important strategic position in national economic development. Among the compositions of the overall innovation system, high-tech industry is one of the most prominent industries with the strongest momentum of development in recent years. The strong independent innovation capacity of high-tech industries in China suggests the strong independent innovation capacity of China. With the implementation of the national innovation-oriented strategy, high-tech industry is experiencing greatly improved size and achievements, which is of great significance for China in marching toward a country of high-quality development.

In recent years, Chinese economy has gradually transformed from extensive to sustainable development. As one of the knowledge-intensive and environment-friendly industries, high-tech industry is an important industrial backing to promote the transformation of green economic development. It also plays an increasingly prominent role in solving the issues of protecting the ecological environment and benign development of the economy. As shown in Figure 1, the research and development institutions,

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including the funds for new product development in the Chinese high-tech industry, show a good development trend increasing annually. As the technology innovation hub, a high-tech industry actively promotes the construction of manufacturing power and greatly drives the deep integration of the Internet, Internet of Things, big data, cloud computing, artificial intelligence, and the real economy. It also supports the transformation and upgrading of traditional industries. Additionally, a high-tech industry fosters new economic growth points and accumulates new kinetic energy of development in accelerating medium- and high-end consumption, leading the innovation development, and achieving green low-carbon, and modern supply chains to promote the industry toward the medium- and high-end global value chain. High-tech industry has great strategic significance for promoting the transformation driven by economic development and speeding up the construction of sci-tech power and quality power. To gain a global competitive edge, China has no choice but to vigorously develop high-tech industries and enhance the independent innovation capacity of high-tech enterprises to be the new engine for world economic growth. Considering the characteristics of high-tech industries, such as high technologies, high risks and short product life cycles, high-tech enterprises are required to possess and constantly improve their independent innovation capacity for survival and development in the intense and changeful market competition.

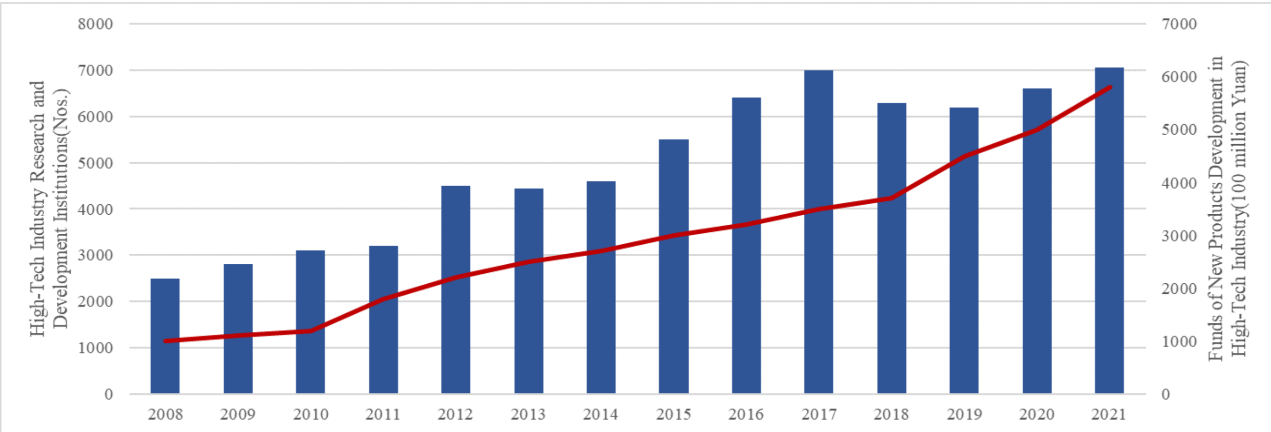

Fig. 1. Research and Development Institutions and Funds of New Product Development in Chinese High-Tech Industries

2. State of the Art

Most of the foreign studies on innovation were based on the theory of technology innovation. Schumpeter, an Austrian economist, was the first to propose the concept of "innovation." As for the scope and meaning of high-tech industries and high-tech enterprises, standard definitions are not uniform for different countries. However, the dominant technology in the identified high-tech field is an essential feature of a high-tech industry as consensus across all countries. As for the influencing factors of innovation and the innovation capacity evaluation of the high-tech industry, Liu et al. [1] used the panel data to empirically study the impact of international technology spillover from different channels on the innovation performance of the Chinese high-tech industry. The results showed that the innovation performance of the Chinese high-tech industry was determined by the international source of technology spillover and Chinese independent efforts together. Parida et al. [2] made reference to data from 252 high-tech small and medium-sized enterprises (SMEs). The results suggested that different open innovation activities favored different innovation outcomes. Using data collected from Dalian High-Tech Industrial Park in China, Pan et al. [3] identified the impact of an innovation network and technology learning on the innovation performance of high-tech cluster enterprises. The results showed that high-tech cluster enterprises improved their innovation performance by not only fostering and optimizing the innovation network but also improving the technology learning capacity. In Pan et al. [4], the essence of sustainable growth for high-tech entrepreneurial enterprises was found to be the effective integration of internal and external innovation resources. The effective mode was group aggregation and chain integration. Lin et al. [5] showed that the high-tech industry should lay stress on market knowledge and customer knowledge management in the innovation practice. In the high-tech industry, knowledge management is transforming customer knowledge into product innovation, by which the market information can be effectively acquired. Liu et al. [6] discussed the relationship between absorptive capacity and innovation performance of Chinese high-tech enterprises. The results showed that, the intellectual capital composed of human capital, structural capital, and relationship capital had a significant impact on acquisition performance, and innovation culture played a partial intermediary role between absorptive capacity and innovation performance. Lin et al. [7] found that management power had a significantly positive impact on innovation performance, which greatly improved the innovation performance of enterprises. Network centrality mediated the enterprise management power and innovation performance. Liu et al. [8] believed that three aspects, that is, regional development conditions, regional consumption potential and innovation subject, had a significant impact on the industrial innovation efficiency of the high-tech industry. Wang et al. [9] evaluated the competitiveness of Chinese high-technology industries using the improved Technique for Order Preference by Similarity to an Ideal Solution (TOPSIS) method, which improved the evaluation results to a certain extent. Fan et al. [10] evaluated the technology innovation capacity (TIC) of high-tech industries in Beijing–Tianjin–Hebei Urban Agglomeration of China by calculating the grey relation projection closeness with the TOPSIS grey relation projection method. The results showed that the TIC of high-tech industries in the Beijing–Tianjin–Hebei Urban Agglomeration of China presented varying degrees of fluctuation and evident regional difference, with the industrial development in a state of moderate imbalance. Based on the data from Chinese large and medium-sized high-tech enterprises in 2011–2013, Li [11] found the relatively most important indicators affecting the innovation capacity of Chinese high-tech enterprises. In addition, the author ranked the innovation capacity of five high-tech industries in China using the gray decision-making method. The results showed that the electronic and telecommunications equipment manufacturing industry and the pharmaceutical manufacturing industry ranked top two in innovation capacity. Su [12] constructed an indication system for evaluating the innovation capacity of Chinese high-tech industries and performed an empirical study using Particle Swarm Optimization in combination with the provincial yearbook data from 30 provinces in China. The results also showed an increasing trend in the overall innovation capacity of Chinese high-tech industries. Hong et al. [13] established an indication system to evaluate the TIC of Chinese high-tech industries. The Fuzzy Borda Method was applied to the evaluation of the innovation capacity of high-tech industries. The results showed the good value of the evaluation model based on the fuzzy Borda combination for guiding the analysis of real technology innovation data in 2013. Zeng [14] proposed the induced fuzzy number of intuitive fuzzy Hamacher-related average operator and conducted the calculation taking the evaluation on TIC of high-tech enterprises as an example. Wang et al. [15] considered TIC a complex, elusive and uncertain concept, and evaluated the comprehensive performance of high-tech enterprises using the fuzzy measurement and non-additive fuzzy integration methods. The analysis results demonstrated the non-additive fuzzy integration method as effective, simple, and suitable for identifying key indicators for influencing factors of high-tech enterprises. Gao et al. [16] analyzed the innovation capacity of agricultural high-tech enterprises from the perspectives of technology and system based on first-hand survey data from 125 agricultural high-tech enterprises. The results showed that the overall level of Chinese technology innovation was barely acceptable, and the TIC investment capacity surpassed the implementation and output capacities. Zeng et al. [17] constructed an evaluation system for the innovation capacity of the science and technology parks through the empirical study of Qingdao Science and Technology Park (1994–2008). The results showed that the evolution law explained by the three-component fitting evaluation system remained consistent with the actual evolution process of Qingdao Science and Technology Park. Lam et al. [18] showed a significant association between knowledge management with innovation capacity. In an open innovation culture, the mutual trust, collaboration, and learning promoted by supporting and participating leaders are more likely to improve the efficiency of knowledge management practices. External sources of innovation presented a positive correlation with innovation activities and new product performance. Law et al. [19] found a positive correlation between the external innovation sources of high-tech manufacturing enterprises with innovation activities and new product performance. Barrett et al. [20] demonstrated the importance of “doing, applying, and interactive” learning mode for SMEs. Blichfeldt et al. [21] found that companies with a higher level (breadth and depth) of digital technology implementation might introduce more aggressive products and service innovations. Gawel [22] conducted a study on high-tech technology enterprises in EU countries from 2009 to 2018 and found the significant impact of high-tech internationalization on the entrepreneurial rate. The existing research literature demonstrated that, among all the analysis data worldwide, the independent TIC of high-tech enterprises was valued by scholars worldwide. On the contrary, the analysis of independent innovation capacity had just begun, with not much analysis and evaluation on the meaning of independent innovation capacity. From the current measurement methods, the overall indication level for the independent innovation capacity of the objects to be evaluated was given by the evaluation results. However, nothing reflected the deficiency and level of independent innovation capacity for high-tech industries within the industry and measurement category. Moreover, more scholars still have shortcomings when expanding the nature of the independent innovation capacity for high-tech industries.

In this study, a more systematic, scientific, and comprehensive evaluation indication system for high-tech industries was constructed based on the existing research literature. Moreover, the independent innovation capacities of high-tech enterprises in different provinces of China from 2000 to 2020 were measured and evaluated, taking the evaluation of the independent innovation capacity of high-tech industries in 31 Chinese provinces as an example. The objectives are to essentially understand the characteristics of high-tech enterprises and high technology and improve the scientific measurement of independent innovation capacity pertinence of high-tech industries.

3. Methodology

3.1 Modeling

Diakoulaki proposed the Criteria Importance Through Intercriteria Correlation (CRITIC) method to deal with the comprehensive weight of multiple attribute decision-making. Comprehensive weight was achieved for multiple evaluation indicators by applying the CRITIC method to the evaluation of the independent innovation capacity of Chinese high-tech enterprises in this study. Comprehensive weight considered the contrast and the conflict among evaluation indicators to comprehensively measure the objective weight of evaluation indicators. The steps of calculating the combinational weight of evaluation indicators by the CRITIC method are as follows, with Eq. (1) defined as the evaluation decision-making matrix.

$$D = \begin{bmatrix} d_{11} & \cdots & d_{1n} \\ \vdots & \vdots & \vdots \\ d_{1n} & \cdots & d_{mn} \end{bmatrix} \quad (1)$$

In Eq. (1), d_{ij} is the element for evaluating the matrix D. The standardization process is required to obtain the standardized evaluation decision-making matrix Q to eliminate the influence of inconsistent dimensions and orders of magnitude for original evaluation indicators if any. Then, the correlation coefficient among the evaluation indicators r_{ij} was derived to form the correlation coefficient matrix $R = (r_{ij})_{m\times n}$, where r_{ij} is shown in Eqs. (2) and (3).

$$r_{ij} = \frac{\text{cov}(d_i, d_j)}{\sqrt{Dd_i}\sqrt{Dd_j}} \quad (2)$$

$$\text{cov}(d_i, d_j) = E(((d_i - E(d_i)) \cdot (d_j - E(d_j))) \tag{3}$$

The amount of information and weight of each evaluation attribute are derived. The objective weight of each evaluation indicator shall be comprehensively measured by evaluating the contrast and conflict of the evaluation indicators. C_j expresses the amount of information contained in the J^{th} evaluation indicator:

$$C_j = \sigma_j \sum_{i=1}^{n} (1 - r_{ij}), j = 1, 2, \cdots, n \tag{4}$$

In Eq. (4), σ_j is the standard deviation of the J^{th} evaluation indicator. The objectivity of the CRITIC method was reflected by evaluating the contrast and conflict of evaluation indicators. The weight in the CRITIC method synthesized the contrast and conflict of evaluation indicators. Evidently, a greater C_j indicates the greater amount of information contained in the J^{th} evaluation indicator and, accordingly, the higher relative importance of the indicator. Therefore, the weight w_j is expressed by Eq. (5).

$$w_j = \frac{C_j}{\sum_{j=1}^{n} C_j}, j = 1, 2, \cdots, \text{n} \tag{5}$$

Finally, the standardized weighted evaluation decision-making matrix V is constructed as shown in Eq. (6).

$$V = \begin{pmatrix} d_{11} \cdot w_{11} & d_{12} \cdot w_{12} & \cdots & d_{1n} \cdot w_{1n} \\ d_{21} \cdot w_{21} & d_{22} \cdot w_{22} & \cdots & d_{2n} \cdot w_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ d_{m1} \cdot w_{m1} & d_{m2} \cdot w_{m2} & \cdots & d_{mn} \cdot w_{mn} \end{pmatrix} \tag{6}$$

TOPSIS is characterized by easy understanding, simple calculation, a wide range of applications, intuitive geometric meaning, reasonable results, and others. The application of TOPSIS to the evaluation of the independent innovation capacity of Chinese high-tech enterprises has the following advantages. TOPSIS theory allows reasonable ranking and comprehensive decision-making of multiple evaluation indicators and obtains the specific members of the evaluation indicators. However, the quantitative data of the evaluation indicator should be evaluated in this method, and the distance of each proposal between the ideal solution and the negative ideal solution is used for calculation. As a result, TOPSIS is greatly influenced by the degree of dispersion of the indicators. For this reason, TOPSIS was combined with the CRITIC method in the study to reduce the above deficiencies. The principles of TOPSIS calculation are as follows. Based on the standardized weighted evaluation decision-making matrix, the positive and negative ideal solutions are defined for multiple evaluation indicator decision-making. The distance between the proposal and the positive ideal solution and that between the proposal and the negative ideal solution are calculated respectively to obtain the comprehensive evaluation value of each proposal (i.e., the relative closeness distance between the evaluated and optimal proposals). Finally, the proposals are ranked by their comprehensive evaluation values. The evaluation result is better when the comprehensive evaluation indicator is closer to the positive ideal solution but farther from the negative ideal solution, reflecting a more ideal proposal. The details of the calculation are described as follows. First, based on the standardized weighted evaluation decision making matrix, the positive ideal solution V^+ and negative ideal solution V^- are calculated, as shown in Eqs. (7) and (8), respectively.

$$\begin{aligned} V^+ &= (v_1^+, v_2^+, \cdots, v_j^+, \cdots, v_n^+) \\ v_j^+ &= \{(\max_{1 \le i \le m} v_{ij} \mid j \in J^+), (\min_{1 \le i \le m} v_{ij} \mid j \in J^-)\} \end{aligned} \tag{7}$$

$$\begin{aligned} V^- &= (v_1^-, v_2^-, \cdots, v_j^-, \cdots, v_n^-) \\ v_j^- &= \{(\min_{1 \le i \le m} v_{ij} \mid j \in J^+), (\max_{1 \le i \le m} v_{ij} \mid j \in J^-)\} \end{aligned} \tag{8}$$

Euclidean distances from the proposal to the positive ideal solution and to the negative ideal solution are calculated, as shown in Eq. (9).

$$\begin{aligned} D_j^+ &= \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^+)^2} \\ D_j^- &= \sqrt{\sum_{j=1}^{n} (v_{ij} - v_j^-)^2} \end{aligned} \tag{9}$$

Finally, the relative closeness of the proposal is calculated, as shown in Eq. (10).

$$C_i = \frac{D_i^-}{D_i^+ + D_i^-} \tag{10}$$

3.2 Indication System

Establishing a systematic, comprehensive, and objective indication system is the foundation for scientific evaluation, which requires operability, comparability, and scientificalness in combination with quantitative and qualitative principles. According to the connotation and characteristics of high-tech industries, by reading and studying the literature regarding the innovation capacity indicators of high-tech industry, an indication system for the innovation capacity of Chinese high-tech industries was constructed in this study, as shown in Table 1, in a combination of qualitative and quantitative methods, which has been validated for the correlation and applicability.

Table 1. Indication System for Innovation Capacity of Chinese High-Tech Industries

Primary indicators	Secondary indicators	Unit
Economic indicators for high-tech industries	Number of production and operation enterprises	Nos.
	Annual average number of employees	Persons
	Gross value of production and operation output at current prices	One hundred million CNY
	General assets	One hundred million CNY

	Income from the main business	One hundred million CNY
	Total profit	One hundred million CNY
	Delivery value of export	One hundred million CNY
Technology acquisition and technology transformation indicators	Expenditure on technology transformation of large and medium-sized high-tech industry enterprises	Ten thousand CNY
	Expenditure on technology import of large and medium-sized high-tech industry enterprises	Ten thousand CNY
	Expenditure on technology assimilation of large and medium-sized high-tech industry enterprises	Ten thousand CNY
	Expenditure on purchasing domestic technology of large and medium-sized high-tech industry enterprises	Ten thousand CNY
R&D-related activities and staff indicators	Number of enterprises with R&D activities	Nos.
	R&D staff	Persons
	Full-time equivalent of R&D staff	Man-year
	R&D internal expenditure–labor	Ten thousand CNY
	R&D internal expenditure–enterprises funded	Ten thousand CNY
	R&D external expenditure	Ten thousand CNY
Fixed assets and fixed assets investment indicators of high-tech industry	Number of newly commenced projects	Nos.
	Number of projects completed or put into use	Nos.
	Rate of projects completed and put into use	Percentage
	Rate of renovation and reformation projects completed and put into use	Percentage
	Amount of investment in fixed assets	One hundred million CNY
	Amount of investment in infrastructure	One hundred million CNY
	Amount of investment in renovation and reformation	One hundred million CNY
High-tech products import and export indicators	Total amount of import and export	One million dollars

4. Results Analysis

4.1 Descriptive Statistical Results

Table 1 shows a very imbalanced development trend of high-tech industries in 31 provinces of China. The large standard deviation indicates an evident regional imbalance in the development of high-tech industries in 31 provinces of China. The high-tech industries in the eastern region of China have apparent advantages over the central and western regions. Owing to the relatively undeveloped level, the high-tech industries in the central and western regions have a larger potential for development. The differences in the introduction of high-tech industry projects, research and development (R&D) investment, and preferential policies result in the greatly varying growth rates of high-tech industries among these provinces, which accordingly lead to a large gradient change in the development of high-tech industries. From another aspect, the regional economic development strategy plays an evident role in developing high-tech industries. In some provinces in the central and western regions, such as Heilongjiang, Shanxi, and Ningxia, high-tech industries are developing at a relatively stable level. This case is probably the result of insufficient impetus from the local government to high-tech industrialization or the relatively backward local economic conditions incapable of laying the foundation for the rapid development of high-tech industries.

Table 2. Descriptive Statistical Results

Item	Min.	Max.	Mean	Standard deviation	Median
Number of production and operation enterprises	10.5	5281.357	785.176	1125.126	449.357
Annual average number of employees	27.976	2943995.762	315870.799	579641.655	169490.024
Gross value of production and operation output at current prices	5.055	34537.407	4865.379	7603.127	2436.49
General assets	16.679	19005.5	2414.671	3856.268	1193.19
Income from the main business	7.354	22875.953	2728.815	4780.867	1337.243
Total profit	2.526	1170.877	170.861	259.449	100.716
Delivery value of export	0.036	11881.812	1103.44	2516.766	222.833
Expenditure on technology transformation of large and medium-sized high-tech industry enterprises	0.19	599773.922	88239.265	130245.983	34668.693
Expenditure on technology import of large and medium-sized high-tech industry enterprises	2.521	390712.276	31246.62	74641.647	3141.398
Expenditure on technology assimilation of large and medium-sized high-tech industry enterprises	48.913	24060.171	3604.372	5617.67	1032.711
Expenditure on purchasing domestic technology of large and medium-sized high-tech industry enterprises	85	162075.41	10535.92	29208.646	2670.449
Number of enterprises with R&D activities	9.69	1949.723	315.786	468.81	162.106
R&D staff	247.657	195961.402	22093.199	38895.542	11562.377
Full-time equivalent of R&D staff	177.946	163632.041	16928.289	31396.894	8407.97

R&D internal expenditure–labor	4.989	2842330.986	216531.299	518822.678	64549.986
R&D internal expenditure–enterprises funded	6.067	4929133.541	488848.663	943326.192	219881.579
R&D external expenditure	54.573	629752.064	55235.781	114899.808	22777.528
Number of newly commenced projects	12.231	1558.787	322.527	350.739	207.645
Number of projects completed or put into use	2.025	1499.055	265.427	308.766	161.948
Rate of projects completed and put into use	0.293	67.347	47.676	12.867	50.529
Rate of renovation and reformation projects completed and put into use	0.686	59.529	37.281	11.634	38.404
Amount of investment in fixed assets	18.434	1888.713	398.059	400.188	226.719
Amount of investment in infrastructure	0.01	1514.662	88.688	293.009	11.202
Amount of investment in renovation and reformation	0.02	1298.606	109.573	271.66	19.874
Total amount of import and export	0.03	297357.744	26968.376	61254.882	4366.316

4.2 Determination of Weight by the CRITIC Method

As shown in Table 3, CRITIC weight is calculated by the variability and the conflict of the evaluation indicators. According to Eqs. (1)–(6), the final weight is calculated by normalizing the amount of information. From the table, the top five indicators are the rate of renovation and reformation projects completed and put into use; the amount of investment in renovation and reformation; the rate of projects completed and put into use; the gross value of production and operation output at current prices; and the expenditure of large and medium-sized high-tech enterprises on technology reformation. These indicators are the critical factors affecting the ranking of high-tech industries at the provincial level.

Table 3. CRITIC Weight Calculation Results

Item	Indicator Variation	Indicator conflict	Amount of information	Weight
Number of production and operation enterprises	0.213	5.754	1.228	2.52%
Annual average number of employees	0.197	5.782	1.138	2.34%
Gross value of production and operation output at current prices	0.22	12.51	2.754	5.66%
General assets	0.203	5.809	1.18	2.42%
Income from main business	0.209	5.688	1.189	2.44%
Total profit	0.222	5.598	1.243	2.55%
Delivery value of export	0.212	6.13	1.298	2.67%
Expenditure on technology transformation of large and medium-sized high-tech industry enterprises	0.217	10.038	2.18	4.48%
Expenditure on technology import of large and medium-sized high-tech industry enterprises	0.191	8.051	1.538	3.16%
Expenditure on technology assimilation of large and medium-sized high-tech industry enterprises	0.234	9.407	2.201	4.52%
Expenditure on purchasing domestic technology of large and medium-sized high-tech industry enterprises	0.18	7.963	1.436	2.95%
Number of enterprises with R&D activities	0.242	6.647	1.606	3.30%
R&D staff	0.199	5.819	1.157	2.38%
Full-time equivalent of R&D staff	0.192	6.144	1.18	2.42%
R&D internal expenditure–labor	0.183	7.396	1.35	2.77%
R&D internal expenditure–enterprises funded	0.191	6.215	1.189	2.44%
R&D external expenditure	0.182	8.027	1.465	3.01%
Number of newly commenced projects	0.227	9.424	2.137	4.39%
Number of projects completed or put into use	0.206	9.883	2.038	4.19%
Rate of projects completed and put into use	0.192	19.868	3.812	7.83%
Rate of renovation and reformation projects completed and put into use	0.198	22.112	4.372	8.98%
Amount of investment in fixed assets	0.214	9.851	2.108	4.33%
Amount of investment in infrastructure	0.193	18.1	3.501	7.19%
Amount of investment in renovation and reformation	0.209	18.974	3.969	8.15%
Total amount of import and export	0.206	6.896	1.421	2.92%

4.3 TOPSIS Results

According to Eqs. (7) – (10), TOPSIS calculation is conducted on the mean indicator of 31 Chinese provinces in 2000–2020. Table 4 shows the results.

Table 4. TOPSIS Calculation Results

Province	Relative closeness C	Ranking
Beijing	0.111	7
Tianjin	0.061	13
Hebei	0.037	18
Shanxi	0.018	22
Inner Mongolia	0.006	26
Liaoning	0.052	16
Jilin	0.018	21
Heilongjiang	0.023	19
Shanghai	0.159	5
Jiangsu	0.444	2
Zhejiang	0.22	3
Anhui	0.058	14
Fujian	0.124	6
Jiangxi	0.052	15
Shandong	0.188	4
Henan	0.076	10
Hubei	0.09	9
Hunan	0.063	11
Guangdong	0.95	1
Guangxi	0.015	23
Hainan	0.005	27
Chongqing	0.04	17
Sichuan	0.102	8
Guizhou	0.02	20
Yunnan	0.009	24
Tibet	0.0001	31
Shaanxi	0.062	12
Gansu	0.006	25
Qinghai	0.001	30
Ningxia	0.004	28
Xinjiang	0.002	29

As shown in Table 4, Guangdong ranks first, followed by Jiangsu and Zhejiang sequentially. The differences in economic and geographical factors initially result in the regional distribution imbalance of high-tech industries, typically "the eastern preceding over the middle, and the middle preceding over the western." In the eastern region, the favorable economic environment and abundant economic resources further promote the high agglomeration and rapid development of high-tech industries. On the contrary, the lack of improved infrastructure and human resources, including the difficulty of policy supports, slow down the development of high-tech industries in the central and western provinces. As a result, high-tech industries in China are highly concentrated in the eastern provinces. In addition to the output, the technology also presents a high degree of uneven distribution among provinces. The high-tech industries in Shaanxi, Guizhou, Heilongjiang, Ningxia, Qinghai, and Jiangxi have a relatively low level of specialization. In these provinces, the R&D cycle is longer for high-tech enterprises. Thus, a little carelessness will frustrate the transformation of commodities from scientific research achievements to productivity, and eventually, a high commercial value is impossible. In these economically backward provinces, high-tech industries excessively depend on government support, usually based on preferential policies and other favorable conditions for high-tech industry development zones or industrial parks. However, the subsequent development mainly comes from the increased efficiency in the industrial agglomeration and improved external environment instead of developing the enterprises in the zone through knowledge spillover while driving the flourishing development of high-tech enterprises in surrounding areas through the high-tech industrial agglomeration.

5. Policy Suggestions

5.1 A strategic planning of high-end development should carry on.

In addition to encouraging the diversified development of high-tech industries, Chinese governments at all levels should avoid repetitive constructions at the low level, remain vigilant in the industry isomorphism, encourage the gradient transfer of similarized industries to undeveloped regions, and minimize the negative externality of industrial agglomeration to promote the high quality and efficient development of high-tech industries. Exchanges and cooperation of high-tech industries should be intensified among different regions, particularly at the provincial level. The objectives are to give full play to the inter-regional spillover effect of technical efficiency in high-tech industries and achieve mutually beneficial development between the high-tech industries and the traditional industries and also among regions. For those regions with relatively undeveloped economic conditions, particularly for the central and western regions and Northeast China, policies should be more preferential to the high-tech industries based on the existing distribution of high-tech industries, to actively create software and hardware environment favoring the development of high-tech industries. In relatively well-developed regions, a new path of industrialization and informatization should be followed to prioritize modern agriculture, deep energy processing, equipment manufacturing, and strategic emerging industries in light of their own endowment. Moreover, relying on the transportation hub and regional central cities, the diversified agglomeration level of high-tech industries should be motivated to strengthen the correlation effect among industries and promote the upgrading of overall technology efficiency by guiding a whole region with one unit and transforming the old with the new.

5.2 Great importance should be attached to the cultivation and introduction of talents in high-tech industries.

The investment in human capital of high-tech industries improves not only the endogenous innovation capacity of various industries in the region but also the capacity to identify, assimilate, and absorb technologies out of the region. All regions are suggested to vigorously develop higher education, attach much significance to the balanced development of education at all levels, and advocate lifelong education to improve the capacity of talent cultivation within the region. According to the strategic orientation and planning of regional economic development, all regions should attract and introduce talents accurately and fully considering the economic, social, and environmental carrying capacity in the region to avoid an imbalance supply–demand structure of talents. Governments at all levels should ascertain an effective implementation of talent policies, establish creative and dynamic mechanisms, and improve the level of medical, health, and social security services, achieving the introduction and retention of talent. The mechanism for technology transfer of high-tech industries should be improved, and more high-tech enterprises should be encouraged to carry out the industrialization of independent innovation achievements. Moreover, service industries for the transfer and transformation of R&D achievements are vigorously developed to accelerate the commercial application of scientific and technological achievements. The construction of markets is intensified in the human resources, technology, and intellectual property elements, and innovation is promoted for business patterns of technology finance.

5.3 The regional distribution should be optimized for national high-tech industries.

As a highly concentrated zone of high-tech enterprises, national high-tech zones carry the important mission of promoting technology innovation, leading industrial upgrading, and promoting high-quality economic development. National high-tech zones also actively promote the improvement of technical efficiency in neighboring areas. Overall, the spatial imbalance is still found in the development of Chinese national high-tech zones. Most of the highly developed national high-tech zones are distributed in the Beijing–Tianjin–Hebei Urban Agglomeration, the Bohai Rim, the Yangtze Plain, Middle and Lower, the southeast coastal area, and Chengdu–Chongqing region. The State and all regions should intensify the preferential policies for the construction of high-tech industrial parks along the east-west direction to further optimize the spatial distribution of national high-tech zones, particularly in the north of the Yangtze River basin, highlighting the upper and middle reaches of Yellow River basin, the north central of Northeast China, and others. The national high-tech zones serve as the carrier to build and improve the regional innovation system, giving full play to their role of radiation impetus. Furthermore, provinces should continue to deepen exchanges and cooperation to further consolidate the radiation impetus of national high-tech zones. Those technologically developed regions are also encouraged to provide technological pairing assistance to technologically backward areas. Additionally, governments at all levels are suggested to continue the support the development of high-tech zones and implement preferential policies for high-tech zones in factor supply, taxation, technology research, and talent introduction.

6. Conclusion

A high-tech industry is an industry with innovative technologies and abundant human resources. The powerful innovation capacity of high-tech industries plays an important role in transforming economic growth from extensive to resource-saving mode. In this study, a combination of CRITIC and TOPSIS methods was adopted to evaluate the innovation capacity of high-tech industries in 31 provinces of China. The study concluded as follows: (1) The top five indicators are the rate of renovation and reformation projects completed and put into use; the amount of investment in renovation and reformation; the rate of projects completed and put into use; the gross value of production and operation output at current prices; and the expenditure of large and medium-sized high-tech enterprises on technology reformation. These indicators are the most critical factors affecting the ranking of high-tech industries at the provincial level; (2) Guangdong ranks first, followed by Jiangsu and Zhejiang sequentially, showing the regional distribution imbalance of high-tech industries, typically "the eastern preceding over the middle, and the middle preceding over the western." Future research could design a set of accurate and handy evaluation indication systems, evolving around the elements composing independent innovation capacity and the interaction among these elements for high-tech industries in different provinces.

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