Industrial Engineering and Innovation Management (2024)
Clausius Scientific Press, Canada

DOI: 10.23977/ieim.2024.070202
ISSN 2522-6924 Vol. 7 Num. 2

Estimation of Green Innovation Capability in the Yellow River Basin: A Case Study of Shandong Province

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Keywords: Improving green innovation capability; Economic perspective; Entropy weight TOPSIS; Euclidean distance

Abstract: Promoting green innovation capability is of great significance to China's realization of green economic power and green innovation power. Based on the perspective of economic development, this paper establishes a comprehensive evaluation system for improving regional green innovation capability from 19 indicators in five aspects, including green innovation input, green innovation output, green development, talent development and utilization, and economic benefits, and uses the entropy weight TOPSIS method to estimate the green innovation capability of Shandong Province from 2012 to 2022. On this basis, the European distance method is used to identify the key influencing factors. The results show that the overall green innovation capability of Shandong Province is on the rise, but the speed of green innovation capability improvement is slightly lower than the speed of green innovation input; Under the average level of green innovation during the sample period, green innovation input, green innovation output, green development, and talent development and utilization have promoting effects on the improvement of green innovation ability, but the economic benefits fail to meet the requirements of promoting green innovation ability.

1. Introduction

Since the reform and opening up, China's economy has grown at a faster rate than the world average, and at the same time has continued to advance at a faster rate than its own average. With the acceleration of industrialization and rapid economic development, China's environmental problems have gradually become prominent and more intense, and ecological environment problems have become the bottleneck restricting the sustainable development of China's economy. Facing the severe problems of resources, energy and ecological environment, green innovation has become a hot topic in the research of China's economic development. Improving regional green innovation capability is of great significance for the realization of China's "double carbon" goal [1]. In the report of the 18th National Congress of the Communist Party of China, the importance of scientific and technological innovation was further emphasized, and its indispensable important position in the improvement of social productivity and the enhancement of comprehensive national strength was clarified.

Based on the above analysis, this paper is arranged as follows: Section 1 Introduction; The second section reviews and summarizes the existing research contributions and shortcomings; The third section designs a new index system for the level of green innovation ability, and selects relevant index data as the data support for measuring green innovation ability. The fourth section constructs a comprehensive evaluation model to provide theoretical support for the calculation of green innovation capability; The fifth section expands the model calculation and analyzes the possible main reasons according to the difference calculation results. The sixth section is conclusion and prospect.

The main contributions of this paper are as follows: (1) Propose the connotation of green innovation capability upgrading from a new perspective, design a set of green innovation capability measurement index system, measure the effect of green innovation capability upgrading, and provide theoretical and data support for the improvement of green innovation capability in the Yellow River Basin; (2) Due to the large number of indicators used, the Euclidean distance method is adopted in this paper to calculate the Euclidean distance between indicators, solve the problem that the dimension of measurement indicators exceeds three dimensions, and set standard values for comparison and analysis, so as to effectively obtain the key influencing factors and the results of their promoting and inhibiting effects.

2. Literature review

(1) Research on the assessment of green innovation capability

Zhao Shaofei (2020) constructed an evaluation index system for regional industrial green technology innovation from the perspective of green technology support capacity, green technology input capacity and green technology output capacity, adopted the improved closeness value method to conduct an empirical analysis on the industrial green technology innovation capacity of 30 provinces in China, and divided the regional industrial green technology innovation level into five categories to analyze the regional industrial green technology innovation level in China The inter-provincial differences in color technology innovation were evaluated [2]. Liang Yingping (2020) combined and empowered three subjective and objective weighting methods based on the principle of minimum deviation degree, established an optimized weighting model, and studied the green innovation capability of eight cities in the Yangtze River Delta [3]. Bai Mingguo et al. (2021) constructed an evaluation index system of urban green innovation capability from three aspects: green innovation input, green innovation output and green innovation environment optimization. Taking the panel data of 16 prefecture-level cities in Anhui Province from 2011 to 2017 as samples, the global entropy method was used to calculate the ranking of each city's green innovation capability [4]. Ye Chenyi et al. (2022) took listed industrial enterprises from 2016 to 2020 as the research object, built an evaluation system for the green innovation ability of industrial enterprises, and on this basis focused on 288 industrial enterprises in the Beijing-Tianjin-Hebei region, and revealed their internal development difficulties by factor analysis and cluster analysis. Moreover, a panel regression model was established to empirically analyze the correlation between macro environmental factors and green innovation capability [5]. Chen Songyi (2023) quantitatively screened the index system by using R-clustering and variation series 13/22 number method, and finally determined the evaluation index system of green innovation ability of high-tech industries. On this basis, the cloud model evaluation method is further introduced to conduct a comprehensive evaluation and analysis on the green innovation capability of China's high-tech industries from 2009 to 2020 [6].

(2) Research on the impact of green innovation capability on regional economic development

In terms of the impact on regional economic development, Cheng Li (2016) concluded that the current development status of Tianjin is relatively good, and the overall development is toward a high-level level through the spatial evaluation method of the coordinated development of regional environmental economy [7]. Zhang Zhiying et al. (2019) took 30 provinces in China as research objects, built a green innovation indicator system, and used a spatial econometric model to study the relationship between green innovation and regional economic growth [8]. Chen Guoqing et al. (2020) established an evaluation system of green innovation and economic development, and used the data of Sichuan Province from 2007 to 2018, such as the gross regional economic product, R&D expenditure and scientific and technological innovation investment, to establish a grey correlation analysis model and study the relationship between the two [9]. Ou Lingyan (2020) studied the extent and direction of the impact of green technology innovation on regional economic growth from a spatial perspective based on the fixed effect variable coefficient regression model [10]. Based on the theoretical analysis results, Wang Wei (2021) constructed the index system of regional green innovation and digital economy, selected indicators reflecting regional characteristics, used TOPSIS model based on entropy weight method for comprehensive evaluation, used the coupled development model improved by Gini coefficient to measure the coupling degree and coupling development degree of green innovation and digital economy, and made contributions to the coupling development degree Degree decomposition [11]. Wang Shuai (2022) used the dynamic panel GMM model to estimate the direct effect of digital economy on green development, and Wei Shiwei (2022) used urban panel data to investigate the impact of digital economy on urban green innovation output and its mechanism from the perspective of green technology innovation [12-13]. Based on the data of 11 provinces and cities along the Yangtze River Economic Belt from 2005 to 2019, Wang Fuyuan (2022) calculated the level of high-quality economic development by entropy weight method, and applied the spatial Durbin model to analyze the impact of environmental protection, green technology innovation and high-quality economic development [14]. Zhai Renxiang et al. (2022) empirically analyzed the relationship between green technology innovation and energy use efficiency in China's coastal areas [15]. Gu Huidong et al. (2022) conducted an empirical analysis of the spatial effect of green technology innovation on carbon emissions based on the spatial Durbin model [16].

(3) Research on influencing factors of green innovation capability

In terms of influencing factors of green innovation capability, Luo Chengyu (2019) used the partial least squares model to analyze the influence of various dimensions of green innovation environment on green innovation capability [17]. It is concluded that economic development level, policy support intensity, fixed asset investment and infrastructure construction have significant positive effects on the improvement of green innovation capability, while population expansion scale and natural resource endowment have no significant effects on the improvement of green innovation capability. Dapeng Li (2021) Using entropy method, Their index, improved gravity model, social network analysis, Granger causality test, grey correlation analysis and Tobit regression model, this paper measures the level value of green innovation capability of 28 cities in the middle reaches of the Yangtze River from 2008 to 2018, analyzes its spatial-temporal evolution characteristics, and explores the influencing factors of the development and change of green innovation capability [18].

To sum up, at present, there are a lot of researches on the evaluation of green innovation capability by domestic and foreign scholars, and the research methods are extensive. However, most researches on the evaluation of green innovation capability mainly focus on the evaluation of enterprises' green innovation capability, and there are few researches on the evaluation of provinces' and regions' green innovation capability. In terms of the impact of green innovation ability on regional economic development, domestic and foreign scholars mainly study the impact of green technology innovation ability on regional economic development, with relatively few studies on green innovation ability, and even fewer studies on the impact of green innovation ability on the economy of various provinces in the Yellow River Basin, so it is necessary to increase scientific research investment in this field.

3. Index selection and data source

3.1. Index system construction

The factors affecting regional green innovation ability are complex and diverse, and there is no unified index system for evaluating regional green innovation ability at present. In order to evaluate regional green innovation capability, this paper adheres to the principles of comprehensiveness, comparability, representativeness and feasibility of index selection, and analyzes the connotation of green innovation capability from the perspective of innovation based on the evaluation index system established in existing literatures. A comprehensive evaluation system for regional industrial transformation and upgrading has been established from a total of 25 indicators in 5 aspects, including green innovation capacity input, green innovation output, green development index, talent development and utilization index, and industrialization level. The specific indicator system is shown in Table 1.

(1)Economic level, which is used to reflect the degree of economic development of a country or region, includes four indicators: per capita GDP, per capita disposable income, tertiary industry added value index, and tertiary industry added value as a proportion of GDP.

(2)Green innovation investment is used to reflect the capital and time investment of a country or region in green innovation, including the full-time equivalent of R&D personnel of industrial enterprises above designated size, R&D funds of industrial enterprises above designated size, the number of R&D projects of industrial enterprises above designated size, and the average number of students in colleges and universities per 100,000 population.

(3)The output of green innovation is used to reflect the results of green innovation in a country or region, including five indicators: the expenditure of industrial enterprises above designated size for the development of new products, the sales revenue of new products of industrial enterprises above designated size, the number of effective invention patents of industrial enterprises above designated size, the turnover of technology market, and the engineering and technical personnel of public economic enterprises and institutions.

(4)The green development index is used to reflect the resource conservation and sustainable development capacity of a country or region, including three indicators: investment in industrial pollution control, investment in ecological construction and protection in the current year, and forest coverage.

(5)The talent development and utilization index is used to reflect the development and utilization of human resources in a country or region, including three indicators, such as the number of working people studying for doctoral degrees, the number of master's degrees awarded, the per capita education funding, and the registered urban unemployment rate.

3.2. Data source

This paper takes Shandong Province as an example to measure green innovation capacity and identify possible key influencing factors. Considering the availability of data, this paper selects relevant index data from 2012 to 2022 for measurement, and the data comes from the National Bureau of Statistics. For some missing data, interpolation method is adopted in this paper.

Table 1: Green innovation ability comprehensive evaluation index system and weight

Target layer	Criterion layer (Weight)	Index layer (unit)	nature	weight
Green innovation capability evaluation index	Economic level (0.1509)	GDP per capita (Yuan/person)	+	0.0415
		Per capita disposable income (Yuan)	+	0.0427
		Value-added Index of Tertiary Industry (previous year =100)	-	0.0322
		Value-added of the tertiary industry as a percentage of GDP (%)	+	0.0345
	Green innovation input (0.2582)	Full-time equivalent of R&D personnel in industrial enterprises above designated size (man-year)	+	0.0699
		R&D expenditure of industrial enterprises above designated size (ten thousand yuan)	+	0.0302
		Number of R&D projects of industrial enterprises above designated size (items)	+	0.0963
		Average number of students in institutions of higher learning per 100,000 population (persons)	+	0.0618
	Green innovation output (0.3311)	Expenditure for developing new products for industrial enterprises above designated size (ten thousand yuan)	+	0.0420
		Sales revenue of new products of industrial enterprises above designated size (ten thousand yuan)	+	0.1096
		Number of valid invention patents of industrial enterprises above designated size	+	0.0579
		Technology market turnover (RMB 100 million)	+	0.0994
		Engineering and technical personnel of public economic enterprises and institutions	+	0.0222
	Green development (0.1492)	Investment in industrial pollution control (ten thousand yuan)	+	0.0759
		Investment in ecological construction and protection completed this year (ten thousand yuan)	-	0.0412
		Forest coverage (%)	+	0.0321
	Talent development and Make use of (0.1107)	Number of doctoral and master's degrees awarded to working personnel (10,000)	+	0.0329
		Per capita education expenditure (Yuan/person)	+	0.0534
		Urban registered unemployment rate (%)	-	0.0244

4. The construction of comprehensive evaluation model

The evaluation of green innovation capability involves a number of indicators, which need to be evaluated by a multi-indicator evaluation method. TOPSIS method is a method to sort the evaluation objects based on the closeness between the evaluation objects and the ideal solution, and evaluate the advantages and disadvantages of the objects. This method can make full use of the original data information of each index, effectively reduce information loss, and make the evaluation results of innovation ability more appropriate to the actual situation. Therefore, TOPSIS method was chosen to calculate the comprehensive evaluation index of green innovation capability in the Yellow River Basin. The premise of applying TOPSIS method is to reasonably determine the weight of each index. Entropy weight method can calculate the corresponding weight according to the dispersion degree of each evaluation index by using information entropy. The calculation result can reduce the interference of subjective factors and is highly objective, so it is a more widely used objective weighting method. In order to effectively reduce the interference of subjective factors and objectively evaluate the green innovation ability of each province in the Yellow River Basin, this paper combines the entropy weight method with TOPSIS method and uses the entropy weight method to determine the weight of each index. The specific steps of entropy weight TOPSIS method are as follows:

(1) Construct a decision matrix $X=\left(x_{ij}\right)_{(m\times n)}$, where i represents the year and j represents the evaluation index of green innovation capability. In order to eliminate the difference of dimensions and orders of magnitude, the original matrix is standardized by using the min-max standardization method, and the standardized matrix $X'=\left(x'_{ij}\right)_{(m\times n)}$ is obtained. The calculation formula is as follows

$$x'_{ij}=\begin{cases}\dfrac{x_{ij}-\min\left(x_{ij}\right)}{\max\left(x_{ij}\right)-\min\left(x_{ij}\right)}, & x_{ij}\ \text{is a positive indicator}\\ \dfrac{\max\left(x_{ij}\right)-x_{ij}}{\max\left(x_{ij}\right)-\min\left(x_{ij}\right)}, & x_{ij}\ \text{is a negative indicator}\end{cases} \tag{1}$$

(2) Calculate the information entropy of the JTH index:

$$E_j=-\frac{1}{\ln m}\sum_{i=1}^{m} y_{ij}\ln y_{ij},\quad \left(j=1,2,\cdots,n\right) \tag{2}$$

In the formula $y_{ij}=\dfrac{x'_{ij}}{\sum_{i=1}^{m} x'_{ij}}$,assume when $y_{ij}=0$,having $y_{ij}\ln y_{ij}=0$.

(3) Calculate the weight of the JTH indicator (see Table 1 for the results):

$$W_j=\frac{1-E_j}{\sum_{j=1}^{n}\left(1-E_j\right)},\quad \left(j=1,2,\cdots,n\right) \tag{3}$$

(4) The weighted standardized matrix can be obtained from the standardized matrix and the weight of each index:

$$Z=\left(z_{ij}\right)_{(m\times n)},\ z_{ij}=W_j\times x'_{ij} \tag{4}$$

(5) According to the calculation of the matrix Z, the ideal solution I_j^+ and the negative ideal solution I_j^- and the negative ideal solution:

$$I_j^+ = \max\left(z_{1j}, z_{2j}, \cdots, z_{mj}\right), \quad I_j^- = \min\left(z_{1j}, z_{2j}, \cdots, z_{mj}\right) \tag{5}$$

(6) The Euclidean distance method is used tocalculate the distance between thezijand the ideal solution z_{ij} and the ideal solution I_j^+ and negative ideal solution I_j^- of each index:

$$D_i^+ = \sqrt{\sum_{j=1}^{n}\left(i_j^+ - z_{ij}\right)^2}, \quad D_i^- = \sqrt{\sum_{j=1}^{n}\left(i_j^- - z_{ij}\right)^2}, \quad (i = 1, 2, \cdots, m) \tag{6}$$

(7) Calculate the comprehensive evaluation index:

$$C_{\text{i}} = \frac{D_i^-}{D_i^+ + D_i^-}, \quad (i = 1, 2, \cdots, m), \quad 0 \le C_{\text{i}} \le 1 \tag{7}$$

The larger the Ci value, the closer it is to the optimal state, indicating the better the green innovation ability.

5. Evaluation of industrial transformation and upgrading effect and identification of influencing factors

5.1. Analysis of comprehensive evaluation results

Based on the established evaluation index system, this paper uses entropy weight TOPSIS method to calculate each evaluation index. First, the weight of 19 indicators was determined by entropy weight method, and then TOPSIS method was used to calculate the evaluation index of each criterion layer, and the evaluation index of each criterion layer was arithmatically averaged to obtain the comprehensive evaluation index of industrial transformation and upgrading of Shandong Province. The calculation results are shown in Table 2. In order to further explore the change trend of each index and comprehensive index, the change trend of each criterion layer index and comprehensive index of industrial transformation and upgrading is drawn, as shown in Figure 1.

Table 2: Standard index and comprehensive index of green innovation ability (2012-2022)

A given year	Green innovation input	Green innovation output	Green development	Talent development and utilization	Economic level	Composite index
2012	0.0161	0.1092	0.3717	0.4342	0.4665	0.2795
2013	0.0891	0.2239	0.4214	0.4599	0.4796	0.3348
2014	0.1326	0.2660	0.4359	0.4677	0.4835	0.3571
2015	0.1667	0.2938	0.4437	0.4717	0.4857	0.3723
2016	0.2147	0.3298	0.4549	0.4774	0.4887	0.3931
2017	0.262	0.3615	0.4669	0.4835	0.4919	0.4131
2018	0.2721	0.3655	0.4651	0.4827	0.4916	0.4154
2019	0.2575	0.3585	0.4667	0.4836	0.4922	0.4117
2020	0.4979	0.4882	0.4988	0.4997	0.5001	0.4970
2021	0.8563	0.7037	0.5546	0.5277	0.5146	0.6314
2022	0.9981	0.9734	0.7039	0.6072	0.5547	0.7678

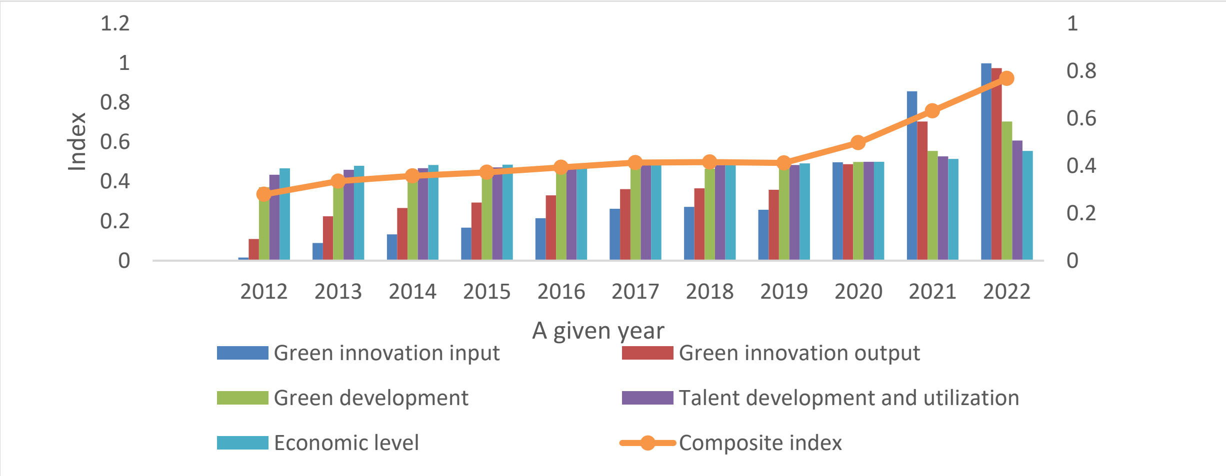

Figure 1: The change trend of standard level index and comprehensive index of green innovation ability (2012-2022)

According to the calculation results and change trend, the comprehensive index of green innovation capability of Shandong Province from 2012 to 2022 shows a steady upward trend, except for a slight decline in 2019. Among them, the growth rate from 2012 to 2019 slowed down, with an average annual growth rate of only 5.78%, and the growth of transformation and upgrading was weak; From 2020 to 2022, the growth rate will be faster, with an average annual growth rate of 24.29%; This is closely related to the release and implementation of Shandong Province's 2021 Implementation Opinions on the Green, Low-carbon and High-quality Development of Science and Technology Leading Industries.

In the trend of index change of each criterion layer, there are obvious differences among each index. Green innovation input and green innovation output grew rapidly during the sample period, with an average annual growth rate of more than 20%. Green development, human resources development and utilization, and economic level are slowly growing. Specifically, the green innovation input index increased from 0.0161 in 2012 to 0.9981 in 2022, with an average annual growth rate of 51.09%, but experienced a period of decline during 2017-2019; The green innovation output index experienced a relatively large growth trend from 2012 to 2017, began to decline after 2017, and rebounded in 2020, 2021 and 20223. The green development index showed a slow growth, but the range was small, with an average annual growth rate of only 6.59%, which was significantly lower than the expected growth rate. Talent development and utilization showed a slow growth, with an average annual growth rate of 3.41%; The economic level index shows a flat trend from 2012 to 2022, with an average annual growth rate of only 1.75%.

5.2. Identification of key influencing factors

On the basis of entropy weight TOPSIS method, Euclidean distance method is used to calculate the distance between each index and the optimal solution and the worst solution. The specific calculation results are shown in Table 3 and Table 4.

Table 3: Distance between each index and optimal solution in Euclidean space

A given year	Green innovation input	Green innovation output	Green development	Talent development and utilization	Economic level
2012	0.0539	0.0422	0.0041	0.0258	0.0454
2013	0.0078	0.0041	0.0455	0.0576	0.0641
2014	0.0728	0.0782	0.0724	0.0719	0.0717
2015	0.2604	0.1676	0.0907	0.0808	0.0760
2016	0.2457	0.1619	0.0916	0.0813	0.0763
2017	0.2558	0.1651	0.0906	0.0809	0.0762
2018	0.3059	0.1919	0.0979	0.0843	0.0779
2019	0.3614	0.2247	0.1051	0.0877	0.0796
2020	0.4035	0.2518	0.1102	0.0901	0.0808
2021	0.4607	0.2958	0.1200	0.0948	0.0831
2022	0.5651	0.4338	0.1569	0.1113	0.0908

Table 4: Distance between each index and worst solution in Euclidean space

A given year	Green innovation input	Green innovation output	Green development	Talent development and utilization	Economic level
2012	0.5191	0.4814	0.1801	0.1074	0.0757
2013	0.3327	0.1799	0.0757	0.0616	0.0552
2014	0.0477	0.0435	0.0481	0.0485	0.0487
2015	0.0005	0.0062	0.0350	0.0417	0.0452
2016	0.0001	0.0074	0.0345	0.0413	0.0450
2017	0.0003	0.0067	0.0351	0.0416	0.0451
2018	0.0042	0.0025	0.0308	0.0392	0.0438
2019	0.0127	0.0002	0.0269	0.0369	0.0425
2020	0.0216	0.0002	0.0244	0.0354	0.0416
2021	0.0363	0.0031	0.0201	0.0325	0.0400
2022	0.0694	0.0290	0.0085	0.0239	0.0349

Because the Euclidean distance method does not consider the weight of variables, but the purpose of key factor identification is to consider which index has a greater impact on green innovation capability. Therefore, according to the close degree of variables and the comprehensive index of green innovation capability in reality, this paper selects the level index representing the development degree of regional green innovation as the standard value in identification and analysis. Then the relationship between other variables and the standard value is found. If the value of other variables is greater than the standard value, it indicates that there is a positive impact on the improvement of green innovation ability, and the larger the value, the greater the impact. If the value of other variables is less than the standard value, it indicates that there is a negative impact on the improvement of green innovation ability, and the smaller the value, the greater the impact. The Euclidean distance of each variable is calculated as follows:

$$X_j = \sqrt{\sum_{i=1}^{m}\left(x_{ij}^{+} - x_{ij}^{-}\right)^2},\ \left(j = 1, 2, \cdots, n\right) \tag{8}$$

In the formula, Xj represents the Euclidean distance value of the JTH variable, the distance value of the optimal solution of the JTH variable in year i (the initial value is set to 1, with 2012 as the starting year), and the distance value of the worst solution of the JTH variable in year i. After obtaining the Euclidean distance value of each variable, the difference S to measure the influence size is obtained by comparing it with the standard value. The calculation formula is as follows:

$$S_j = \left| X_j - X_1 \right|,\ \left(j = 2, \cdots, n \right) \tag{9}$$

Where, Sj represents the influence degree of the JTH variable on green innovation capability, and X1 represents the standard value represented by the level of green innovation. The specific results obtained are shown in Table 5.

Table 5: Influence degree of each variable on green innovation ability in Euclidean space

	Green innovation level (standard value)	Green innovation input	Green innovation output	Green development	Talent development and utilization	Economic level
Influence degree	0.1414	1.4790	1.1870	0.4794	0.2194	0.0963
Difference value	0	1.3376	1.0456	0.3380	0.0780	-0.0451

As can be seen from Table 5, green innovation input has the largest positive impact, the difference between it and the standard value is 1.3376, followed by green innovation output, the difference between it and the standard deviation is 1.0456. In addition, green development, talent development and utilization also have positive impact, the difference between them is 0.3380 and 0.0780 respectively. The economic level has a negative effect, with a difference of -0.0451, indicating that from 2012 to 2022, among the factors affecting green innovation capability, green innovation input and green innovation products have a significant promoting effect on green innovation capability of Shandong Province, while green development and talent development and utilization also have a relatively small promoting effect on green innovation capability. Economic benefits fail to meet the requirements of improving green innovation ability, but have a negative impact. As the economic foundation is the support of green innovation, it is also the main driving force for the improvement of green innovation ability. Talent development and utilization, green innovation investment and green development are closely related to economic level.

6. Research conclusions

From the perspective of innovation management, based on literature review such as evaluation of green innovation level effect and analysis of influencing factors of transformation, this paper takes indicators such as green innovation input, green innovation output, green development, talent development and utilization, and economic level of Shandong Province from 2012 to 2022 as research samples. The entropy weight TOPSIS method is used to measure the effect of industrial transformation and upgrading, and the key influencing factors are identified based on the European distance method. The findings are as follows:

(1)The overall effect of green innovation in Shandong Province showed a steady upward trend. The average annual growth rate of the comprehensive index of green innovation level from 2012 to 20222 is 10.63%, indicating that the pace of industrial transformation and upgrading in Shandong Province is relatively slow compared with economic growth. In 2019, there was even a negative growth rate of the comprehensive index of green innovation level, but in 2020, this situation has been significantly improved, and the growth rate of the comprehensive index has risen significantly, reaching 20.72%, which is closely related to policy support.

(2)There are obvious differences among the indicators of each influencing factor. Among them, green innovation input and green innovation output grew rapidly during the sample period, with an average annual growth rate of 51.09% and 2.45%, respectively. The indicators of green development, talent development and utilization, and economic level showed slow growth and anaverage growth rate of positive during the sample period.

(3)The influencing factors are characterized by three positive and three negative laws. Under the existing industrialization level, talent development and utilization, green innovation input, green innovation output, and green development have a promoting effect on green innovation ability, and the economic efficiency level fails to meet the requirements of promoting industrial transformation and upgrading, which may have a certain inhibiting effect.

The shortcoming of this paper is that the improvement of green innovation ability is not only related to the economy, but also affected by the environment of green innovation. Especially in the context of the introduction of green development policies in the new era, the green innovation environment has strongly promoted the regional green innovation development. Aiming at the effect evaluation of green innovation capability and identification of influencing factors, this paper basically does not involve green innovation environmental indicators, so the research on green innovation environmental indicators remains to be explored.

References

[1] Gao shan, Analysis of spatial-temporal evolution and influencing factors of green technology innovation capability in urban agglomeration in the middle reaches of the Yellow River [D]. Shanxi university of finance and economics, 2023. DOI: 10.27283 /, dc nki. GSXCC. 2023.001280.

[2] ZHAO Shaofei, Zhao Xin, Chen Xiang. Evaluation of regional industrial green technology innovation capability based on improved closeness value method [J]. Industrial Technical Economics, 2020, 39(07):152-160. (in Chinese)

[3] Fang Chengwu, Liang Yingping, Wu Fan, et al. Based on the performance of green technology innovation ability evaluation study [J]. Journal of nanyang institute of technology, 2020, 12 (5): 27-32. DOI: 10.16827 / j.carol carroll nki. 41-1404 / z. 2020.05.005.

[4] Bai Mingguo, Fu Yinglu, Yao Yuting. Urban green innovation ability evaluation research in anhui province [J]. Journal of innovation of science and technology, 2021, 21 (02): 49-57, DOI: 10.19345 / j.carol carroll XKJ. 1671-0037.2021.02.006.

[5] Ye Chenyi, Huang Can, Wang Shang, et al. Evaluation of green innovation capability and environmental driving factors of industrial enterprises in Beijing-Tianjin-Hebei [J]. Business Research, 2022, 29(06):36-49.

[6] Chen Songyi. High technology industry innovation ability evaluation index system of green building and measure [J]. Journal of statistics and decision, 2023, 33 (3) 6:174-178. The DOI: 10.13546 / j.carol carroll nki tjyjc. 2023.03.032.

[7] Cheng L. Spatial evaluation method of coordinated development of regional environmental economy [D]. Tianjin Normal University, 2016. (in Chinese)

[8] Zhang Zhi-Ying, Yue Yuan-xi. Spatial econometric analysis of the relationship between green innovation and regional economic growth [J]. Special Zone Economy, 2019,(08):101-103.

[9] Chen Guoqing, Fang Ziqiang, Long Yunan. Empirical study on the relationship between green innovation and economic development in Sichuan Province: Based on grey correlation analysis [J]. Economic Perspective, 2020, (05):81-89.

[10] Ou Lingyan. Green technology innovation's influence on the regional economic growth research [D]. Nanjing university of science and technology, 2020. The DOI: 10.27241 /, dc nki. Gnjgu. 2020.000730.

[11] Wang Wei. The Chinese provincial green innovation and coupling of digital economy development research [D]. Zhejiang industry and commerce university, 2021. The DOI: 10.27462 /, dc nki. GHZHC. 2021.000772.

[12] Wang Shuai. Influence on the development of the digital economy of regional green study [D]. Lanzhou university, 2022. The DOI: 10.27204 /, dc nki. Glzhu. 2022.003664.

[13] Wei Shiwei, Du Jinmin, Pan Shuang. Digital economy how to promote green innovation -- empirical evidence from Chinese city [J]. Journal of business review, 2022, (11): 10 to 20. The DOI: 10.13762 / j.carol carroll nki CJLC. 20220308.001.

[14] Wang Fayuan, He Zhili, Zhang Dongqing. Environmental protection, green technology innovation and high-quality economic development: An empirical analysis based on the data of the Yangtze River Economic Belt from 2005 to 2019 [J]. Yangtze River Basin Economic Research, 2022,(01):91-111.

[15] Zhai Renxiang, Shi Zheyu. Whether green technology innovation can improve energy efficiency: A case study of China's coastal areas [J]. Ocean development and management, 2022, 33 (4): 6-49. 43 DOI: 10.20016 / j.carol carroll nki hykfygl. 20220330.015.

[16] Gu Huidong, Yang Weiguang, Chen Wenjie. Study on the effect of green technology innovation on urban carbon emission reduction [J]. Academic Exploration, 2022,(03):120-132.

[17] Luo Chengyu. Regional differences and influencing factors of green innovation capability in China [D]. Xi 'an University of Technology, 2019.

[18] Li Dapeng. Urban agglomeration in the middle reach of Yangtze river green innovation ability of space and time characteristics and influencing factors of research [D]. Hunan normal university, 2021. The DOI: 10.27137 /, dc nki. Ghusu. 2021.002306.