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Green Innovation Capability of High-Tech Industry in Yangtze River Economic Belt and its Spillover Effect

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Abstract: As an important pillar of comprehensive national power, the innovation capacity of high-tech industries has always been a hot spot for research. This paper considers environmental factors and selects panel data of 11 provinces(cities) in Yangtze River Economic Belt (YREB) from 2011-2020 to study the green innovation capacity of their high-tech industries and its spillover effects. Finally, the following conclusions are drawn: (1) the green innovation capacity of provinces(cities) in the YREB shows a large gap between them, showing the geographical characteristics of "high in the east and low in the west"; (2) The direct and spillover effects of government support on green innovation in high-tech industries in each region are the largest; increasing government funding support for R&D can effectively enhance the green innovation capacity within each region and between regions.

Keywords: Yangtze River Economic Belt; High-tech Industry; Green Innovation Capacity; Spillover Effect.

1. Introduction

As China's economy gradually enters the stage of high-quality development, innovation capability has gradually become the core engine of development. Among them, the green innovation capability which is both environmentally friendly and economically efficient has received wide attention. Through scientific research and development of green products and upgrading of traditional processes, it can save resources and reduce waste emissions (Jens Horbach et al., 2012) [1]. Green innovation ability is one of the decisive factors for the success of new products of enterprises (Siba et al., 2023) [2]. In recent years, it has gradually become the key point for the integrated development of high-quality cities in the YREB (Li Yuwen et al., 2022) [3], and is of great significance in promoting the transformation and upgrading of traditional industries (Fu Xiu-Mei et al., 2022) [4].

High-tech industry is an important industrial support for promoting green transformation. Scholars' attention on high-tech industry mostly focuses on competitiveness (Li Wenqian et al., 2017; Luyuan Tang, 2022)[5-6], innovation ability (Zhou Yanju et al., 2014)[7] and innovation efficiency (Hu Yidong et al., 2011)[8]. Of course, in order to realize the vigorous development of China's high-tech industry, attention must be paid to the improvement of green innovation ability (Chen Songyi, 2023)[9]. However, it can be seen that the research on green innovation evaluation of high-tech industry has not been deeply discussed, which restricts the development of green innovation ability to a certain extent.

The YREB is one of the regions with the greatest strategic support for China. Scientific evaluation of the impact of economic activities on ecological environment is of great significance for promoting the transformation development of the YREB. Therefore, based on high-tech industries in the YREB, this paper explores the spillover effect of green innovation capability.

2. Methods and Materials

2.1. Construction of green innovation capability evaluation system

Based on the existing research, this paper constructs a green innovation capability index system for high-tech industries in the YREB from three perspectives: green innovation input, green innovation output and green innovation supporting environment, and introduces relevant indicators measuring ecological environment.

This paper selects 13 indicators, R&D staff , Full-time Equivalent of R&D Personnels , R&D personnel as a proportion of all employees , Average number of students enrolled in higher education schools per 100,000 population , R&D expenditure , R&D investment intensity , Investment in R&D of new products, Number of enterprises in high technology industry , Number of Research and Development Institutes , Total public library collections , Environmental pollution control completed investment , Wastewater Investment and Waste gas investment ,to reflect the green innovation input capacity.

This paper selects 9 indicators, Number of patent applications, Number of valid invention patents, Number of new product development projects, Total profit of high technology industry, New product sales revenue, Total export trade of new products, Total wastewater discharge, Solid waste generation and Emissions of smoke (dust) from exhaust gases, to reflect the green innovation output capacity.

This paper selects 9 indicators, Gross Regional Product, Disposable income of urban residents, Green area per capita, Labor cost per R&D personnel, Government funds in R&D expenditure, Education expenses, Technology market turnover contract amount, Health technicians per 1,000 population and Internet broadband access port, to reflect the green innovation environment support capacity.

2.2. Factor analysis method

According to the existing literature, factor analysis is selected in this paper to measure the green innovation capability of high-tech industries in 11 provinces of YREB. Factor Analysis is a multivariate statistical method that uses the dimensionality reduction method for statistical analysis. The specific mathematical model is shown as follows.

$$\begin{cases} X_1 = a_{11}F_1 + a_{12}F_2 + \cdots a_{1m}F_m + e_1 \\ X_2 = a_{21}F_1 + a_{22}F_2 + \cdots a_{2m}F_m + e_2 \\ \cdots \\ X_p = a_{p1}F_1 + a_{p2}F_2 + \cdots a_{pm}F_m + e_p \end{cases} \quad (1)$$

Where $X_1, X_2, \cdots, X_p$ are the results of p original variables after normalization, $F_1, F_2, \cdots, F_m$ are m factor variables, and $m < p$, denoting the matrix as $X = AF + e$.

2.3. Spatial econometric model

This paper establishes the spatial Dubin model constructed by Lesage and Pace to study the spatial impact of each variable on the green innovation ability of 11 provinces (cities) in the YREB.The formula is as follows:

$$\ln GIC_{it} = \rho W \ln GIC_{it} + \beta_0 + \beta_1 \ln T_{it} + \beta_2 \ln O_{it} + \beta_3 \ln I_{it} + \beta_4 \ln G_{it} + \beta_5 W \ln T_{it} + \beta_6 W \ln O_{it} + \beta_7 W \ln I_{it} + \beta_8 \ln W G_{it} + \mu_i + \phi_t + \varepsilon_{it} \quad (2)$$

Among them, GIC_{it} represents the green innovation ability of high-tech industry in region i in year t; T_{it} represents the ratio of highway mileage to railway mileage and land area in the t year of region i ; O_{it} represents the proportion of the total import and export volume of region i in GDP in the t year ; I_{it} represents the proportion of the tertiary industry in region i in year t; G_{it} represents the ratio of government funds to GDP in the t year R&D expenditure of region i; W is the economic distance matrix ; μ_i, ϕ_t and ε_{it} represents individual fixed effect , time fixed effect and a random error term, respectively.

Transportation infrastructure. Through transportation infrastructure, regions are more closely linked, resulting in the development of a regional transportation infrastructure that can reduce the transportation costs and transaction costs of goods. Increase economic efficiency, and the transportation of goods and personnel is mainly done through transportation.

Openness. The improvement of regional trade openness means that the links between regions become closer, which can alleviate the market segmentation and administrative barriers between regions and contribute to the knowledge spillover between regions.

Industrial structure. By improving the industrial structure of the region, it is conducive to the realization of industrial upgrading between regions, thus making a fundamental change in the energy structure and consumption structure between regions.

Government behavior. The government 's expenditure through R&D can increase the number of high-tech enterprises in the region, which makes the phenomenon of professional agglomeration.

Table 1. Three Scheme comparing

	Symbol	Variables	Definition
Interpreted variable	GIC	Green innovation ability of high-tech industry	Calculated by factor analysis
Explanatory variable	T	Transportation infrastructure	The ratio of the sum of highway mileage and railway mileage to land area/%
	O	Openness	The proportion of total import and export to GDP/%
	I	Industrial structure	The proportion of tertiary industry/%
	G	Government behavior	The ratio of government funds to GDP in R&D expenditure

2.4. Data sources

The original data in this paper can all be obtained directly or indirectly from the China Science and Technology Statistical Yearbook, China High Technology Statistical Yearbook and China Statistical Yearbook and other relevant yearbooks, and for the missing index data, the mean substitution method is uniformly used to supplement them in the processing.

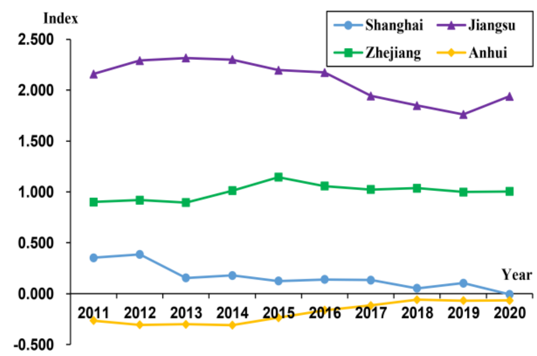
3. Results and Discussion

3.1. Interpretation of Green Innovation Capability Results

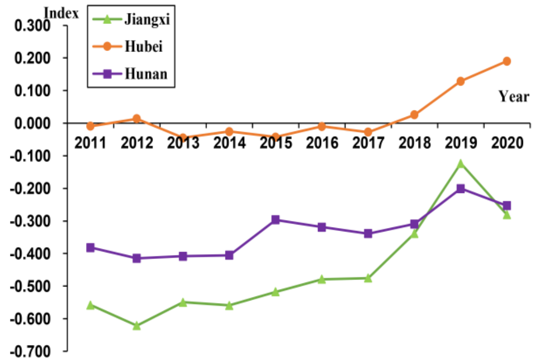
In this paper, through the KMO and Bartlett tests, their KMO values are greater than 0.5 and their p-values are less than 0.05, which meet the basic conditions for applying factor analysis to the data and are suitable for applying factor analysis. Through the data operation, the results are shown in Table 2, and the corresponding images are shown in Figure 1.

As shown in Figure 1, from the overall trend, the green innovation capacity of provinces and cities in China's YREB has a large difference. Except for Shanghai and Jiangsu provinces which show a decreasing trend, the annual average growth rate of green innovation capacity of the remaining nine provinces is on an increasing trend, among which Guizhou and Jiangxi have the largest growth rates, reaching 3.42% and 3.08% respectively.

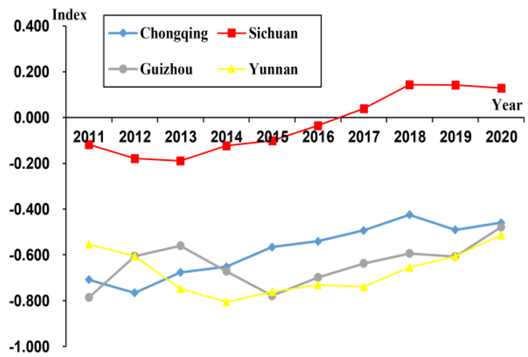
From a geospatial perspective, the green innovation capacity of high-tech industries in the YREB from 2011 to 2020 shows a general trend of "high in the east and low in the west", which is highly correlated with the economic status and openness of each province. However, with China's policy tilt to the western region, the green innovation capacity of high-tech industry in most western provinces has increased significantly.



(a)



(b)



(c)

Fig. 1 Green innovation capacity of high-tech industries in the lower, middle, and upper reaches of YREB

Notes: (a)(b)(c) represent the green innovation capacity of high-tech industries in the downstream, midstream and upstream of the YREB, respectively.

Table 2. Green Innovation Capacity of 11 Provinces in YREB, 2011-2020

Province	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
Shanghai	0.353	0.386	0.154	0.178	0.124	0.140	0.134	0.052	0.103	-0.007
Jiangsu	2.159	2.292	2.316	2.301	2.198	2.174	1.943	1.850	1.762	1.941
Zhejiang	0.901	0.920	0.895	1.012	1.145	1.057	1.024	1.038	0.998	1.004
Anhui	-0.266	-0.306	-0.302	-0.310	-0.236	-0.163	-0.117	-0.059	-0.068	-0.067
Jiangxi	-0.558	-0.621	-0.550	-0.560	-0.518	-0.479	-0.475	-0.339	-0.123	-0.281
Hubei	-0.009	0.013	-0.045	-0.026	-0.042	-0.010	-0.027	0.026	0.129	0.191
Hunan	-0.382	-0.415	-0.408	-0.405	-0.297	-0.319	-0.339	-0.309	-0.200	-0.253
Chongqing	-0.708	-0.766	-0.677	-0.652	-0.566	-0.541	-0.493	-0.425	-0.490	-0.460
Sichuan	-0.117	-0.179	-0.189	-0.123	-0.101	-0.035	0.039	0.143	0.143	0.129
Guizhou	-0.786	-0.606	-0.560	-0.671	-0.779	-0.698	-0.637	-0.594	-0.607	-0.478
Yunnan	-0.554	-0.606	-0.747	-0.806	-0.762	-0.731	-0.740	-0.656	-0.606	-0.513

3.2. Interpretation of spatial model measurement results

Since the green innovation capacity of high-tech industries in the YREB shows obvious geographical differences among provinces and cities, this paper constructs a spatial matrix of geographical distance and economic geographical distance between provinces and cities, and measures the Moran's I based on this to reflect the spatial correlation between the green innovation capacity of high-tech industries in each province and city, it can be seen that the Moran's I of the YREB are all greater than 0, and they all pass the significance test, indicating that the Yangtze River The spatial correlation of the Yangtze River Economic Zone is significant, so the spatial econometric model can be used to further analyze it.

In this paper, the relevant variables were tested (the test results are shown in Table 3) and the model was finally selected as a spatial Durbin model with dual fixed effects of time and individuals according to the sequential principle of Wald statistic > LR statistic > LM's statistic proposed by Anselin.

Table 3. LM, LR and Wald test results

Tests	Statistical quantities	P-value
LM lag	2.448	0.118
Robust LM lag	8.764	0.003
LM error	12.450	0.000
Robust LM error	18.766	0.000
LR Test (SAR)	16.160	0.003
LR Test (SEM)	16.560	0.003
Wald Test (SAR)	16.230	0.003
Wald Test (SEM)	17.510	0.002

In this paper, the spatial effects of each explanatory variable in the spatial Durbin model on the green innovation capacity of high-tech industries in each province and city are decomposed into direct effect, indirect effect and total effect.

Direct effect: As can be seen from Table 4, government support and openness have the most significant role in promoting the existence of green innovation capacity of the local high-tech industry, using the significance test at the 1% level; transportation infrastructure and industrial structure are slightly less significant, passing the significance test at the 5%

level, while government behavior only passes the significance test at the 10% level. Collectively, government support has the largest coefficient, which indicates that through government support, it directly influences the development of local high-tech industry to a large extent. The innovation capability of high-tech industries requires a large amount of R&D funds, however, enterprises often present negative surplus and difficulties in raising funds in the early stage. By increasing R&D funding, the government can largely improve the problem of lack of funds for enterprises. The role of industrial institutions is the second most important factor, mainly because high-tech industries mainly come from the tertiary industry. By increasing the proportion of tertiary industry in the region, the number of local high-tech enterprises can be directly increased, thus helping to promote the local green innovation capacity.

Table 4. SDM double fixed model estimation results and effect decomposition.

Variables	Coefficient	$W \times x$	Direct effects	Indirect effects	Total effects
$ln\,N$	0.105**	0.183	0.098**	0.085	0.183**
$ln\,P$	0.616***	0.395	0.584***	0.140	0.725***
$ln\,G$	1.895***	3.655*	1.701***	2.340*	4.041**
$ln\,I$	123.848*	438.725**	100.593	290.092**	390.685***
rho			-0.440***		
sigma2_e			0.006***		
R-square			0.5492		
Log-Likelihood			130.125		

Notes: *, **, *** indicate passing the significance test of 10%, 5%, and 1%, respectively.

Indirect effects: as can be seen from Table 4, the industrial structure and government supports passed the 5% and 10% significance tests, respectively, while the transportation infrastructure and openness were not significant. The industrial structure shows a positive spillover effect with a coefficient of 2.340, which is mainly due to the fact that the improvement of industrial institutions in neighboring regions helps to improve the industrial structure of providing related support services in the region, which leads to the transformation of energy structure and consumption structure. Government support shows a positive spillover effect with a coefficient of 290.092, mainly because increased government investment attracts high-level talent and the concentration of innovation factors such as information science technology and liquid capital can lead to the formation of specialized clusters in high-tech industries. In addition, the specialized solution also plays a scale effect, realizes the intensive production of industry, makes the comprehensive operation cost of enterprises lower, and can promote the cooperation and exchange of advanced technology, frontier knowledge and management experience among cross-regional enterprises, which is conducive to the knowledge spillover effect, thus improving the economic efficiency of enterprises and stimulating the innovation vitality of industrial development. The spatial spillover effect of high-tech industry agglomeration on regional innovation is higher than the direct effect, and the excessive agglomeration of high-tech industry causes diminishing marginal benefit, thus producing diffusion effect on neighboring regions and positive radiation drive on surrounding areas, forming a regional synergistic development situation. The concentration of high-tech industries has a significant spatial spillover effect and can lead to a substantial increase of regional innovation capacity.

Total effect: As shown in Table 4, the degree of openness and government support both pass the significance test at 1% level, and the transportation infrastructure and industrial structure both pass the significance test at 5% level, and the coefficients of all variables are positive, that is, all four variables have a facilitating effect on the green innovation capability of high-tech industry. Among the promoting effects, the coefficient of the variable of government support is the largest, which is mainly because government support has positive and significant direct and indirect effects on the green innovation capacity of high-tech industry at the spatial level, thus making its total effect positive and large.

4. Conclusions

This paper uses factor analysis to measure the green innovation capability of high-tech industries, and on this basis, uses spatial Durbin models to analyze the spatial clustering characteristics, spatial spillover effects and the driving factors of green innovation capability of high-tech industries in 11 provinces along the YREB from 2011 to 2020. The following conclusions are drawn:

The green innovation capacity of provinces and cities in the YREB is characterized by "high in the east and low in the west". Although Jiangsu and Shanghai in the eastern region are ranked at the top, they have shown a decreasing trend in recent years; the western region is ranked at the bottom in general, but the green innovation capacity has shown an increasing trend in recent years.

From the results of spatial Durbin model, both factors of industrial structure and government support produce positive spillover effects; and it is noteworthy that the direct and spillover effects of government support on regional high-tech industries are much higher than the rest of the factors, which indicates that increasing the government's financial investment in R&D of high-tech industries can effectively enhance the green innovation capacity of the region and the neighboring regions.

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References

[1] Jens Horbach, Christian Rammer, Klaus Rennings: Determinants of eco-innovations by type of environmental impact The role of regulatory push/pull, technology push and market pull, Ecological Economics,, Vol.78(2012), p.112-122.

[2] Borah Prasad Siba, Dogbe Courage Simon Kofi, et al:Green market orientation, green innovation capability, green knowledge acquisition and green brand positioning as determinants of new product success, European Journal of Innovation Management, vol. 26 (2023)No. 2, p. 364-385.

[3] Y.W Li, Y.Q Li, et al:Research on the characteristics and synergy degree of urban green innovation capability in the Yangtze River Delta region,Future and Development, Vol.46(2022) No.10, p.44-51. (In Chinese)

[4] X. M. Fu, W. Y. Wu, C. Y. Lin, H. L. Ku, L. X. Wang, X. H. Lin, Y. Liu: Green innovation ability and spatial spillover effect of marine fishery in China, Ocean and Coastal Management, vol. 228 (2022) No.1, p. 106310.

[5] W.Q. Li,Y. Liu:Technological innovation, corporate social responsibility and enterprise competitiveness-An empirical analysis based on the data of listed companies,Science of Science and Management of S.&.T, Vol.38(2017) No.1, p.154-165. (In Chinese)

[6] L.Y. Tang, G.Q Huo:Research on the evaluation of the competitiveness of high-tech industries-Taking Baoji, Shaanxi as an example,Science and Technology Management Research, Vol.42(2022) No.13, p.28-33. (In Chinese)

[7] Y.J. Zhou, F Zhou, et al:Profitability, Technological Innovation Capability and Capital Structure-Empirical Analysis Based on High-tech Enterprises,Scientific Research Management, Vol.35(2014) No.1, p.48-57. (In Chinese)

[8] Y.D. Hu, W.J. Zhong:An empirical study on the influencing factors of technological innovation performance of high-tech enterprises,Forum on Science and Technology in China, Vol.180 (2011) No.4, p.80-85. (In Chinese)

[9] S.Y. Chen:Construction and measurement of evaluation index system of green innovation ability of high-tech industry, Statistics and Decision, Vol.39 (2023) No.3, p.174-178. (In Chinese)