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Environmental Decentralization and Enterprise Green Innovation

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Abstract

Under the goal of "carbon peaking and carbon neutralization", it is particularly important to reduce the negative externality of environmental problems and promote the green and low-carbon development of enterprises. Green technology innovation can greatly promote regional green development, which requires the government to further promote its development by using environmental governance policies. As one of the basic environmental governance models of the government, it is of great practical significance to explore its impact on the efficiency of green innovation of enterprises. Based on the perspective of "double carbon goals", carbon emissions are included in the evaluation index system of enterprise green innovation efficiency. Using the data of China's provincial industrial enterprises from 2009 to 2018, OLS model and super efficiency SBM model are used to empirically test the nonlinear impact of environmental decentralization on enterprise green innovation efficiency. The research results show that there is a positive U-shaped relationship between the degree of environmental decentralization and enterprise green innovation efficiency, The level of environmental decentralization in Shanxi Province and Hebei Province has entered a stage of promoting the efficiency of green innovation of enterprises. Accordingly, it is suggested that China should carry out structural reform of environmental management power and administrative power, and the degree of environmental decentralization must be set according to different places, so as to better improve the green innovation of regional enterprises.

Keywords

Environmental Decentralization; Green Innovation Efficiency; Super Efficiency SBM Model.

1. Introduction

Since the reform and opening up, China's economic development mode characterized by high energy consumption, high emissions and low efficiency has operated [1]. Under this development mode, China's economy has developed at a high speed and became the world's second largest economy in 2011. However, this has also led to a sharp increase in China's energy consumption and carbon dioxide emissions, leading to frequent extreme weather events such as global warming and greenhouse effect. Environmental problems have seriously restricted the sustainable development of China's economy. The 14th five-year plan proposes to strengthen the construction of ecological civilization, speed up the promotion of green and low-carbon development to a higher level, and the comprehensive green transformation of economy and society has become the long-term goal of China's socialist modernization[2]. The essential requirement of the "double carbon" goal is that economic development tends to be of

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high quality, and green technology innovation is an important support for the construction of ecological civilization and the development of high-quality economy [3]. In this context, green innovation has become an inevitable choice to achieve "win-win" economic effects and environmental protection [4]. Industrial industry is the main industry of energy consumption and carbon emission in China. It is very important to promote green technology innovation of industrial enterprises and speed up energy conservation and emission reduction of industrial enterprises.

Green technology innovation is the main means for enterprises to improve energy efficiency and reduce emissions [5], but because enterprises' green innovation needs to bear high costs and externalities of economic activities, it is difficult to realize the transformation of technological progress to green direction only by market mechanism, which hinders the development of green innovation in China and cannot achieve the goal of high-quality economic development. Therefore, it is necessary for the government to carry out policy intervention on enterprise behavior. Since 2008, the Chinese government has begun to decentralize the environment, improve the freedom of local governments in environmental affairs, and optimize the allocation of functions among governments at all levels [6], which is conducive to the supervision of enterprises within its jurisdiction, especially high pollution enterprises [7]. Will the increasingly perfect environmental decentralization system affect industrial enterprises to carry out green innovation? Exploring this issue will help to promote the realization of the "double carbon" goal, ensure the construction of a new development pattern, and promote high-quality economic development.

2. Literature Review and Theoretical Analysis

2.1. Literature Review

Green technology innovation is a series of technological innovation activities to reduce the use of resources and the cost of environmental pollution protection in the process of product development, production, transportation and use, on the premise of following the ecological objective law (Bernauer et al; 2007) [8]. Scholars have done a lot of research on green technology innovation mainly around the evaluation of green technology innovation and the analysis of influencing factors.

In the comprehensive evaluation of green innovation, the efficiency value of green innovation is mainly used to measure. Academic circles mainly measure the efficiency of green innovation from the perspective of input-output, using research methods such as data envelopment method, production function method and multivariate statistics. For example, Chengyu Li et al. (2018) [9] calculated the industrial ecological innovation efficiency of 30 provinces in China (excluding Hong Kong, Macao, Taiwan and Tibet) from 2006 to 2015 through dea-bcc model and Malmquist index, and analyzed their spatial distribution characteristics by using geoda software, and tested their influencing factors through spatial error model. Tangwei Teng et al. (2019) [10] used the super efficiency SBM (slack based model) model to measure the green innovation efficiency of 26 cities in the Yangtze River Delta. Liming Xiao et al. (2019) [11] used the stochastic frontier analysis method of production function model to explore the green innovation efficiency of Chinese provinces. Guangkuo Gao et al. (2018) [12] used the super minds model to calculate the green innovation efficiency of high pollution industries in Beijing Tianjin Hebei region, and used spatial statistical methods to study their spatial distribution characteristics.

In terms of the construction of the evaluation index system, early studies paid little attention to the environmental effects of innovation. For example, Lingjie Meng and Meng Yan (2015)[13] in the study of using DEA method to calculate the efficiency of China's industrial scientific and technological innovation, the output only includes three expected outputs, such as output value

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and transaction activity, and did not adopt environmental related indicators. However, in recent years, more and more attention has been paid to the green attribute of innovation. For example, Jingyan Fu et al. (2018)[14] constructed a green total factor productivity evaluation index system consisting of three primary indicators of input, expected and unexpected output, and five secondary indicators of capital, labor, energy, emissions of "three wastes" and GDP; Zhe Min et al. (2021) [15]also established a green technology innovation efficiency evaluation index system composed of six indicators, including capital, labor and technology input, innovation result output, economic output and environmental pollution. In terms of environmental effect output, most studies use the "industrial three wastes" (industrial wastewater emissions, industrial sulfur dioxide emissions, industrial dust emissions) to measure, ignoring the carbon dioxide emissions in the process of enterprise innovation and production.

In the exploration of the influencing factors of green innovation, scholars mainly focus on environmental regulation, innovation investment, financial subsidies and other factors. Xie et al. (2017)[16]evaluated the green productivity of China's inter provincial industry through SBM measurement method and luenberge productivity index, distinguished between command-controlled environmental regulation and market regulation environmental regulation, and analyzed the impact of different types of environmental regulation on green productivity. Dabin Meng and Yingying Yu (2022)[17] explored the impact of formal and informal dual environmental regulations on green technology innovation from the perspective of policy mix, and analyzed the regulatory role of green innovation networks in the process of different environmental regulations affecting green technology innovation. Feng Deng and Chunxiang Chen (2020)[18] based on the perspective of environmental regulation, using provincial panel data, studied the nonlinear relationship between r& d investment intensity and China's green innovation efficiency and its differences in time and space. Yue Kong et al. (2021)[19]used the three-stage game method, based on the perspective of Cournot model, obtained the perfect equilibrium solution of the reverse induction sub game, and used comparative static analysis to explore the impact of government subsidies on green technology innovation of new energy enterprises.

Looking at the above literature, scholars at home and abroad have conducted in-depth research on green innovation, but there are also some limitations. When establishing the evaluation index system of green innovation efficiency, scholars mostly ignore the emission of carbon dioxide when considering the output of environmental benefits; In the analysis of the influencing factors of green innovation, scholars have made rich research from the perspective of environmental regulation, and divided environmental regulation into many types, but environmental decentralization, as a means of environmental regulation, has received little attention from scholars. Based on this, this paper makes the following research arrangements: in the context of "double carbon", pay attention to the carbon emissions of enterprises, incorporate carbon dioxide into the evaluation index system of green innovation efficiency, and use super efficiency SBM model to measure the green innovation efficiency of industrial enterprises in 30 provinces of China; And use multiple regression analysis model to explore the impact of environmental decentralization on the efficiency of green innovation.

2.2. Theoretical Analysis

In essence, environmental decentralization discusses the responsibility and power relationship of environmental protection and environmental governance between the central government and local governments [20]. On the one hand, based on the "Porter Hypothesis", environmental decentralization can promote the efficiency of green innovation. First of all, environmental decentralization can make local governments clear their responsibilities, and it is also convenient for local governments to formulate more appropriate environmental regulations or

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more effective environmental governance methods according to local environmental conditions and enterprise needs, so as to promote enterprises to carry out green technology innovation. Secondly, under the decentralized governance mode, the efficiency of the transmission of relevant laws and regulations from the central to local governments has been improved, which not only saves the transmission cost of relevant information, but also improves the implementation effect of laws and regulations, thus promoting the development of green production and environmental protection technology. On the other hand, from the perspective of "pollution paradise" effect, environmental decentralization is not conducive to improving the efficiency of green innovation of enterprises. Due to the influence of administrative system and local performance appraisal, local governments may take environmental decentralization as a means of economic development. According to the "pollution paradise" effect, regions with low environmental protection are more likely to attract foreign investment. In order to retain foreign investment, local governments may reduce environmental governance standards and carry out "bottom-by-bottom competition". In addition, promotion tournaments lead local governments to tilt policy resources to the direction conducive to their own political achievements [21], resources will be tilted to the field of economic construction with low risk and high income, while the field of scientific and technological innovation with high risk and low income will lack resource investment. The above effects will negatively impact regional environmental protection, which is not conducive to green innovation of enterprises.

The impact of environmental decentralization on the efficiency of green innovation of enterprises is not a simple linear relationship. When the degree of environmental decentralization is low, local governments may reduce the intensity of environmental protection to ensure regional economic growth and fiscal revenue, which cannot form a mechanism for environmental protection to force enterprise innovation. At the same time, the decentralization of environmental protection may bring "bottom-by-bottom competition", further leading to the inflow of polluting enterprises, On the contrary, it will inhibit the green technology innovation of enterprises. When the environmental decentralization reaches a certain level, the increase of regional environmental protection will improve the efficiency of government environmental governance, adjust the regional industrial structure, increase the financial revenue of local governments, and reduce the pressure of resource constraints. After that, more funds can be invested in environmental protection, which will encourage local enterprises to carry out green innovation. Therefore, there may be a "U" relationship between environmental decentralization and enterprise green innovation efficiency.

3. Research Design

3.1. Index Selection

3.1.1. Explained Variables

Green innovation efficiency of enterprises. This paper uses the super efficiency SBM model to calculate the green innovation efficiency of China's inter provincial industrial enterprises from 2009 to 2018. Before calculating, input and output indicators need to be determined. Input indicators include labor input, capital input and energy input, and output indicators include economic benefit output and environmental benefit output.

Specifically, r&d expenditure and technological transformation expenditure in capital investment adopt stock indicators, which are estimated by the perpetual inventory method in this paper. Referring to the practice of Xiangdong Li [22]and others, taking 2008 as the base period, the R & D price index is used to reduce the internal expenditure of R & D funds and the expenditure of technological transformation, and the depreciation rate is set to 15%[23]. Labor input is expressed by the full-time equivalent of r& d personnel in

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Industrial Enterprises above Designated Size [24]. The total energy consumption of each province after the industrial standard conversion is put into use [25]; Economic benefit output includes: sales revenue of new products of Industrial Enterprises above Designated Size, number of green invention patent applications and main business income. Among them, the sales income of new products and the main business income are reduced by the ex-factory price index of industrial producers in each province [26], which is uniformly converted into the constant price based on 2008. The output of environmental benefits is measured by the comprehensive index of three wastes and the carbon dioxide emission of industrial enterprises. Here, the negative standardization method is used to process the two data. The comprehensive index of three wastes is obtained by measuring the emissions of industrial sulfur dioxide, industrial wastewater and industrial smoke (powder) dust with the entropy method with reference to the practice of Zhenhong Xiao[27]. The calculation formula is as follows:

(1) The data of the three indicators are negatively standardized to a value between 1 and 100.

$$x_{ij} = 1 + 99 * \frac{\mathrm{Max}\{x_j\} - x_{ij}}{\mathrm{Max}\{x_j\} - \mathrm{Min}\{x_j\}}$$

(2) Calculate the proportion Pi of the j-th index value in the i-th year

$$p_i = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}$$

(3) Calculate the entropy ej of the j-th index

$$e_j = -k \sum_{i=1}^{m} p_{ij} in(p_{ij}), (k > 0, k = \frac{1}{\ln(n)}, 1 \geq e_{ij} \geq 0)$$

(4) Calculate information entropy redundancy

$$d_j = 1 - e_j$$

(5) Calculate the weight of each index

$$W_j = \frac{d_j}{\sum_{j=1}^{m} d_j}$$

With reference to the research of Guimei Zhao [28], the carbon dioxide emissions of industrial enterprises are estimated by using seven kinds of energy, including raw coal, coke, gasoline, diesel, fuel oil, liquefied petroleum gas and natural gas. The calculation formula is as follows:

$$C_i = \sum_{i=1}^{7} E_i \times \lambda_j \times \eta_j \; i = 1,2,3,\ldots,30 \; j = 1,2,3,\ldots,7$$

Where, $C_i$is the estimated carbon emission of province i, λ_i is the conversion coefficient of the j-th energy, $\eta_i$is the carbon emission coefficient of j-th energy, E_i is the actual consumption of j-th energy in province i.

3.1.2. Explanatory Variables

Environmental decentralization. With reference to the index selection method of Junhong Bai et al. [29], the personnel distribution of the central and local environmental protection systems is measured, and the index is reduced by using$1 - (GDP_{it}/GDP_t)$. Among them, GDPit is the GDP of province I in year t; GDPt is the national GDP in t. And Isp_{it} and $Isp_t$are the number of personnel of national and provincial environmental protection agencies in year t; And pop_{it} and $pop_t$are the year-end population size of the whole country and i Province in t year respectively.

The calculation formula is as follows:

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$$EDit = [\frac{Isp_{it}/pop_{it}}{Isp_t/pop_t} \times [1 - (GDP_{it}/GDP_t)]$$

3.1.3. Control Variables

① Economic development level (ingdp): expressed by per capita GDP.

② R & D intensity (RD): measured by the ratio of internal expenditure of r& d funds to GDP.

③ Fiscal Decentralization (FD): use the fiscal freedom index to measure the degree of fiscal decentralization, that is, fd= budget revenue / budget expenditure.

④ Open: it is expressed by the proportion of total import and export in regional GDP.

3.2. Source of Sample Data

This paper explores the relationship between environmental decentralization and green innovation efficiency of enterprises, and takes industrial enterprises in 30 provinces of China (except Tibet, Hong Kong, Macao and Taiwan due to incomplete data) from 2009 to 2018 as the research object From 2010-2019 China Statistical Yearbook, China energy statistical yearbook, China Environment Yearbook "China Science and Technology Statistical Yearbook" and "2006 IPCC guidelines for national greenhouse gas inventories", etc.

3.3. Model Setting

This paper establishes a multiple regression model to test the possible positive "U" characteristics between environmental decentralization and enterprise green innovation efficiency. The model settings are as follows:

$$GI_{it} = \alpha_0 + \alpha_1 ED_{it} + \alpha_2 ED_{it}^2 + \alpha_3 \sum Con_{it} + \varepsilon_{it}$$

Where, GI_{it} refers to the green innovation efficiency of industrial enterprises in Province i in year t; GI_{it} indicates the degree of environmental decentralization of i Province in year t; ED_{it}^2 is the square term of the degree of environmental decentralization, which is used to test the U-shaped relationship between environmental decentralization and enterprise green innovation efficiency; Con_{it} represents the control variable; ε_{it} represents random error term; α_0 is a constant term.

4. Empirical Analysis

4.1. Descriptive Analysis of Sample Data

Table 1. Descriptive statistical analysis (2009-2018)

Variable name	Variable symbol	Sample size	Mean	Standard deviation	Min	Max
Enterprise green innovation efficiency	GI	300	1.002	0.262	0.210	1.570
Environmental decentralization	ED	300	0.984	0.542	0.160	2.890
Economic development level	Ingdp	300	10.656	0.541	6.620	11.850
Economic development level	RD	300	0.988	0.537	0.140	2.190
Fiscal Decentralization	FD	300	0.506	0.192	0.150	0.930
Opening to the outside world	Open	300	0.285	0.324	0.020	1.550

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The descriptive analysis results of each variable are shown in Table 1. In terms of environmental decentralization of the core explanatory variable, the maximum value is 2.890, and the minimum value is only 0.160, indicating that there is significant heterogeneity in the level of environmental decentralization among provinces. In terms of the green innovation efficiency of the explained variable enterprises, the mean value is 1.002 and the standard deviation is 0.262. On the whole, China's green innovation efficiency is high, but the difference between the mean value and the standard deviation is large, indicating that the green innovation level of industrial enterprises in various provinces of China is significantly different.

4.2. Regression Analysis

According to the above theory and OLS regression model, the U-shaped relationship between environmental decentralization and enterprise green innovation efficiency is empirically tested by using stata14.0 software and industrial enterprise data of China's provinces from 2009 to 2018. The results of regression analysis are shown in Table 2.

Table 2. Regression results of the impact of environmental decentralization on enterprise green innovation efficiency

Ols model				
Variable name	Regression coefficient	Standard deviation	T value	P value
ED	-0.397***	0.118	-3.36	0.001
ED^2	0.095**	0 .041	2.31	0.021
Ingdp	-0.048	0.032	-1.49	0.138
RD	0.001	0 .046	0.01	0.999
FD	-0.446**	0 .192	-2.32	0.021
Open	0.318***	0.085	3.72	0.000

Table 2 shows that the primary term coefficient of environmental decentralization is significantly negative (-0.397 * * *) at the level of 1%, and the secondary term coefficient is significantly positive (0.095**) at the level of 5%, indicating that there is a positive U-shaped relationship between environmental decentralization and enterprise green innovation efficiency, which is consistent with the inference in this paper. Before the degree of environmental decentralization reaches the inflection point, the improvement of environmental decentralization inhibits the improvement of enterprise green innovation efficiency. However, when environmental decentralization increases to a certain extent, the improvement of environmental decentralization will be conducive to the improvement of green innovation efficiency of enterprises. According to the calculation, the inflection point of the impact of environmental decentralization on the green innovation efficiency of enterprises is x3=-(-0.397) /2* (0.095) =2.063. Looking up the data, it is found that only the level of environmental decentralization in Shanxi Province and Hebei Province has been on the right side of the inflection point, and its role in promoting the green innovation efficiency of enterprises has entered the stage of promotion. This may be because the coal industry in Shanxi Province and Hebei Province is developed, and the environmental problems it brings are more serious, Under the pressure of environmental protection, its degree of environmental decentralization is higher than that of other provinces, and local governments adopt more appropriate local environmental governance policies to promote green innovation of local enterprises.

5. Conclusion and Suggestions

This paper takes the provincial industrial enterprises in China (mainland) from 2009 to 2018 as the research sample, uses the super efficiency SBM model to measure the green innovation

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efficiency of provincial industrial enterprises, and uses the OLS model to analyze and test the nonlinear impact mechanism of environmental decentralization on the green innovation efficiency of enterprises. The results show that there is a "U" relationship between environmental decentralization and green innovation efficiency, and a low degree of environmental decentralization is difficult to improve the green innovation efficiency of enterprises, A higher level of environmental decentralization is conducive to the improvement of green innovation efficiency. This shows that the level of environmental decentralization of regional governments needs to be further improved in order to give more effective play to the information advantages of local governments, so as to promote the efficiency of green innovation of enterprises.

Based on the above conclusions, this paper puts forward the following suggestions:

1. China's environmental management power and administrative power need structural reform. Based on the conclusion of this paper, on the whole, the level of environmental decentralization in China needs to be improved. Only when local governments obtain greater autonomy can they give better play to their information advantages and improve the efficiency of environmental service supply of local governments. The decentralization of environmental management authority can also make laws and regulations more smoothly implemented, which is conducive to the environmental supervision role of local governments. Under the overall planning and coordination of the central government, it can also promote the formation of the "upward alignment" effect between local governments at all levels in environmental management affairs.

2. The setting of the degree of environmental decentralization varies from place to place. The environmental decentralization in Shanxi Province and Hebei Province has crossed the critical value of the "U" impact of environmental decentralization on the green innovation efficiency of enterprises. Therefore, improving the environmental decentralization in Shanxi and Hebei Province can better promote the improvement of the green innovation efficiency of regional enterprises; For Inner Mongolia and Henan Province, which are about to cross the threshold, it is also necessary to increase the autonomy of local governments in environmental management; The provinces with a large difference between the degree of environmental decentralization and the critical value of "U" shaped impact on the efficiency of green innovation of enterprises should appropriately strengthen environmental centralization and weaken the inhibitory effect of environmental decentralization on the improvement of the efficiency of green innovation of local enterprises.

3. Clarify the responsibilities of governments at all levels in environmental management affairs. Local governments must practice the concept of low-carbon green development, clarify the requirements of the central government and their own work responsibilities, earnestly perform their work responsibilities, take environmental restraint and supervision measures according to local conditions, strengthen the rectification and punishment of heavily polluting enterprises, formulate strict pollution emission standards, strengthen the government's environmental governance capacity, and promote regional green development.

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