

# *Evaluation of Green Innovation Performance of Chinese Chemical Enterprises Based on Entropy Weight Method*

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**Abstract.** Based on the entropy weight method, this study constructs a green innovation performance evaluation system for Chinese chemical enterprises. Taking 164 A-share listed chemical enterprises from 2019 to 2024 as research samples, it evaluates their green innovation performance from four dimensions, namely innovation, economy, society and environment. The results show that social performance has the highest weight, while the economic and innovation dimensions contribute weakly. Accordingly, this study puts forward suggestions such as strengthening industry-university-research cooperation, fostering advantaged industries and promoting balanced regional development, providing references for the green transformation of chemical enterprises.

**Keywords:** Green Innovation Performance, Entropy Weight Method, Chemical Industry

## **1. Introduction**

The Recommendations of the Central Committee of the Communist Party of China on Formulating the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035 emphasizes that the concept of innovation should be implemented in all aspects of China's modernization drive and its core position should be established. The chemical industry not only causes continuous damage to the ecological environment, but also brings potential risks that endanger human health. This urges chemical enterprises to urgently explore a feasible path for the coordinated development of economic and ecological benefits through green transformation and innovation-driven development. Thus, constructing a scientific green innovation performance evaluation system for chemical enterprises, accurately analyzing the development trend of the industry and formulating adaptive strategies are of great significance both in terms of theoretical research deepening and practical application expansion.

## **2. Concept definition**

### **2.1. Green innovation**

Liu et al. [1] proposed that green innovation is an effective way to improve corporate performance by enhancing market competitiveness on the basis of the traditional innovation paradigm. In contrast, when defining the concept of green innovation, Wang Caiming and Li Jian [2] emphasized

that there is an essential difference between this concept and traditional innovation. Green innovation focuses more on applying new technologies and concepts to achieve efficient recycling of resources and strict control of pollution emissions, thereby gaining economic benefits. Weber et al. [3] stressed that the uniqueness of green innovation lies in the need to balance the inherent relationship among economy, society and environment, while paying attention to the integrity and dynamic evolution characteristics of the innovation process, and ultimately promoting resource conservation and curbing ecological damage and environmental pollution. From a broader macro perspective, Xiao Renqiao and Ding Juan [4], Yang Yang et al. [5] defined green innovation as exploration, optimization and application activities carried out by innovation subjects in various aspects such as product design, production processes, manufacturing technologies, organizational structures and management models, with the goal of reducing environmental load and energy consumption.

## 2.2. Evaluation of green innovation performance

The multi-index evaluation of green innovation performance mainly starts from the two aspects of the process and results of green innovation, and conducts a comprehensive evaluation by constructing multiple index systems.

In the evaluation dimension of the green innovation process, the focus is on the efficiency of enterprises in converting innovation input into output during a specific period, and the evaluation model is usually constructed by using two-way input and output indicators. For example, Lü Yanwei et al. [6] set the full-time equivalent of R&D personnel and R&D capital stock as input indicators, and the number of authorized invention patents and sales revenue of new products as output indicators. When studying the green technology innovation efficiency of cities in the Yangtze River Economic Belt, Cheng Shixiong et al. [7] took R&D human resources, funds, energy and other elements as inputs in the scientific and technological R&D stage, and green patents as the output achievements of this stage based on a two-stage model.

In the evaluation dimension of green innovation results, the evaluation system covers three dimensions: environment, economy and society. Xiao Renqiao et al. [8] proposed to adopt the framework of economic performance, environmental performance and social performance to achieve refined evaluation of green innovation achievements. In the research on the evaluation of enterprise green technology innovation performance, Zheng Jiliang et al. [9] also advocated a multi-perspective analysis through the economic dimension (enterprise growth, profitability and solvency), environmental dimension (pollutant discharge and resource utilization) and social dimension (fulfillment of social responsibilities and cultural influence) to ensure the comprehensiveness and accuracy of the evaluation results.

## 3. Construction of green innovation performance evaluation index system for chemical enterprises

In the green technology R&D stage, enterprises focus their core resources on the field of knowledge innovation, and carry out targeted technological breakthroughs by rationally allocating R&D funds and human resources. This process directly affects the formation of enterprise innovation performance. The green achievement transformation stage is oriented towards knowledge application. Enterprises need to effectively embed the technological achievements obtained from previous R&D into business processes such as product design, production and manufacturing, and market promotion, so as to achieve the multiple goals of increasing economic benefits, enhancing

social value and improving the ecological environment. Following the above logic, the green innovation performance of chemical enterprises can be further decomposed into four dimensions: innovation, economy, society and environment, so as to build a more systematic and comprehensive evaluation system.

### 3.1. Innovation performance

Innovation performance reflects the effectiveness of enterprises in technological R&D and product innovation. Its input level can be quantitatively evaluated by indicators such as R&D fund input intensity and R&D personnel ratio. Among them, green patent-related indicators are key elements to measure the technological R&D capability of innovation subjects, which can effectively reflect the strength of innovation subjects in technological innovation and improvement, and are important basis for evaluating the innovation level.

### 3.2. Economic performance

Economic performance is mainly reflected in the improvement of resource use efficiency, labor productivity and reduction of production costs brought by green innovation. Referring to the research results of Zheng Jiliang et al. [9], this study constructs an economic performance evaluation system from two dimensions: profitability and development potential. Among them, profitability indicators directly reflect the income status of enterprises, while development capability indicators can effectively evaluate the growth potential and strategic implementation effect of enterprises.

### 3.3. Social performance

Social performance mainly reflects the contribution degree of enterprise green innovation activities to social welfare and fiscal revenue. This study constructs a quantitative index system, selects the annual total tax payment as the core indicator to measure the fiscal contribution of enterprises, and uses the amount of social public welfare donations to evaluate the fulfillment of their social responsibilities.

### 3.4. Environmental performance

Environmental performance focuses on the actions and inputs taken by enterprises to improve the environment, which can promote green innovation, achieve emission reduction and pollution reduction, and is conducive to the operation and development of enterprises. Referring to previous studies and combining the characteristics of the wind power industry, this paper selects two tertiary indicators: greenhouse gas emission reduction and solid waste discharge.

Table 1. Green innovation performance evaluation index system

Stage	Primary Indicator	Secondary Indicator	Tertiary Indicator	Indicator Calculation Method
Green Technology Innovation Stage	Innovation Performance	R&D Capability	R&D Personnel Ratio (A1)	Number of R&D Personnel / Total Number of Employees
			Number of Green Patent Applications (A2)	Number of Independently Applied Green Invention Patents + Number of Independently Applied Green Utility Model Patents in the Current Year

Table 1. (continued)

Green Achievement Transformation Stage	Economic Performance	Profitability	Number of Authorized Green Patents (A3)	Number of Independently Authorized Green Invention Patents + Number of Independently Authorized Green Utility Model Patents in the Current Year
			Return on Net Assets (A5)	Net Profit / Average Balance of Shareholders' Equity
			Operating Net Profit Margin (A6)	Net Profit / Operating Income
		Development Capability	Total Asset Growth Rate (A7)	Increase in Total Assets in the Current Year / Total Assets at the Beginning of the Year
			Operating Income Growth Rate (A8)	(Current Period Turnover - Previous Period Turnover) / Previous Period Turnover
	Social Performance	Social Responsibility	Amount of Social Donations (A9)	Total Amount of External Donations
			Amount of Tax Payment (A10)	Amount of Enterprise Income Tax Paid
	Environmental Performance	Pollution Emission Reduction	Solid Waste Discharge (A11)	Volume of Solid Pollution Discharged
			Greenhouse Gas Emission Reduction (A12)	Reduction Volume of Carbon Dioxide

## 4. Evaluation of green innovation performance of chemical enterprises

### 4.1. Data sources

This study takes Chinese A-share listed chemical enterprises from 2019 to 2024 as the initial sample pool. The industry classification of chemical enterprises strictly follows the classification standard of the basic chemical industry category in the CSMAR Database Shenwan Industry Classification (2021 Revised Edition). After collecting the data of the sample period, the research reliability is ensured through multi-step data cleaning. First, enterprises that were given special treatment (ST), particular transfer (\*ST) during the sample period and those listed on the capital market after 2019 are excluded. Second, abnormal samples with missing key data or changes in their affiliated industries in the middle are eliminated. After the above processing, 164 enterprises are finally determined as the research samples.

### 4.2. Weight calculation via entropy weight method

#### Step 1: Standardization of Data

Since the indicators included in the green innovation performance evaluation system of this paper involve various aspects of enterprises, the dimension units of the original data are inconsistent and the differences between the data are large, so it is necessary to preprocess the data.

Positive indicators:  $X_{ij} = (X_{ij} - \min X_{ij}) / (\max X_{ij} - \min X_{ij})$

Negative indicators:  $X_{ij} = (\max X_{ij} - X_{ij}) / (\max X_{ij} - \min X_{ij})$

Step 2: Calculate the Proportion of the i-th Evaluation Object under the j-th Indicator

$$P_{ij} = \frac{X_{ij}}{\sum_{i=1}^n X_{ij}}$$

Step 3: Calculate the Entropy Value of the j-th Indicator

$$e_j = -\frac{1}{\ln n} \sum_{i=1}^n P_{ij} \ln P_{ij}$$

When  $P_{ij}=0$  or  $P_{ij}=1$ ,  $p_{ij} \ln(p_{ij})=0$ .

Step 4: Calculate the Difference Coefficient

$$d_j = 1 - e_j$$

Step 5: Determine the Weight

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

### 4.3. Calculation results

The analysis results show that in the primary evaluation index system, the weights of various indicators show significant differences, and their ranking is as follows: social performance > ecological performance > innovation performance > economic performance. Among them, social performance has the highest weight, reaching 0.5752, followed by ecological performance with a weight of 0.3825. This result indicates that in the process of green innovation and development, chemical enterprises need to put the fulfillment of corporate social responsibilities and environmental management in the production process at the core position, and pay special attention to the protection of stakeholders' rights and interests, as well as the improvement and implementation of environmental reward and punishment systems and emergency response mechanisms.

### 4.4. Overall analysis

Among the constituent dimensions of green innovation performance, the weight of social performance indicators accounts for 57.52%, which is in a leading position; the weight of ecological performance is 38.25%, playing an important supporting role; in contrast, the weight of innovation performance is only 2.58%, and the weight of economic performance is even lower, only 1.65%. It can be seen that the economic and innovation dimensions have weak contributions to the green innovation performance system, and their impact on the overall performance is relatively limited.

This study selects the national average value (0.537) of the comprehensive green innovation score during the investigation period as the classification benchmark, and adopts a differentiated

definition method: regions with scores higher than the average are systematically classified as "high-level" regions for green innovation performance; otherwise, they are classified as "low-level" regions. On this basis, a systematic classification study is carried out on the green innovation performance of the provinces where the 164 chemical enterprises in the sample are located, so as to build a differentiated analysis framework and lay a foundation for the subsequent exploration of the characteristics and influencing factors of green innovation development among regions.

The results show that from 2019 to 2024, 7 provinces including Anhui, Beijing and Fujian have always been in the high-level ranks of green innovation performance; while 8 provinces including Guangdong, Hebei and Tibet are classified as low-level regions. Specifically, enterprises in high-level regions such as Gansu and Ningxia have shown stable green innovation performance, and their comprehensive scores over the years are significantly higher than the national average; on the contrary, in low-level regions, Tibet's comprehensive scores have remained at a low level during the five-year investigation period, reflecting that enterprises in this region have great room for improvement in the green transformation of production modes.

## **5. Policy recommendations**

### **5.1. Strengthen industry-university-research cooperation to promote the transformation of innovation achievements**

Compared with the external drive brought by environmental regulation and economic constraints, enterprises need to take the initiative to strengthen the practical application of green innovation achievements. They should avoid confining innovation activities to the R&D stage, but effectively improve the actual effect of green innovation through systematic action plans. As the main force of green innovation, enterprises can deepen the industry-university-research collaborative mechanism and establish normalized cooperative relations with local universities and research institutes to promote the exchange and sharing of technological innovation. At the same time, the government should give full play to its macro-guiding function. It can create favorable conditions for the transformation of scientific research achievements through various measures such as setting up special reward funds, optimizing preferential tax policies, building industry-university-research docking platforms and improving the achievement transformation service system.

### **5.2. Cultivate resource-advantaged industries to drive the collaborative development of secondary industries**

To deeply tap the demonstration value of the chemical fiber industry in the field of green innovation, a systematic cultivation system can be constructed and precise policy support can be implemented to fully activate its local green innovation potential. Then, taking this industry as a leading benchmark, the green transformation process of other secondary sub-industries in the chemical industry can be driven. While strengthening the effectiveness of inter-industry collaborative development, policy intervention needs to adopt differentiated strategies: for agrochemical products, chemical raw materials and rubber products manufacturing enterprises, the government can effectively stimulate the innovation vitality of enterprises by improving the green innovation incentive mechanism, especially increasing the intensity of special subsidies; for enterprises with relatively lagging green innovation capabilities such as chemical products and plastic products, on the basis of ensuring the sustainable operation of enterprises, the focus should be on promoting the green technological

transformation of production equipment, so as to achieve the dual goals of reducing energy consumption and pollution.

### 5.3. Expand the influence of advantageous regions to promote balanced development of all regions

This study constructs a "gradient radiation-collaborative evolution" green innovation development paradigm, and selects leading regions in green innovation performance such as Anhui, Beijing, Fujian and Gansu as core radiation sources. Taking Beijing, the capital city, as an example, while giving play to the talent siphon effect and capital agglomeration effect, a "two-way feedback" mechanism should be established: on the one hand, green innovation elements should be transmitted to surrounding areas through technology output and experience sharing; on the other hand, a cross-regional information exchange platform should be built to form a two-way knowledge flow system of "innovation experience database-failure case pool".

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