# Research on Green Development Level and Efficiency of Chemical Industry Based on AHP and Super-Efficiency SBM Model

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**Abstract.** In the context of the continuous advancement of the "Carbon Peak" and "Carbon Neutral" strategies, green is the main theme of development. To achieve high-quality and sustainable development of the industry, it is necessary to pay attention to the development performance of green laws. In order to measure and evaluate the green development performance of the chemical industry in Gansu Province, this paper takes the chemical enterprises in Gansu Province as the research object, uses the AHP method to construct a green development performance evaluation index system. At the same time, the paper uses the super-efficiency SBM model to calculate the green development efficiency of the chemical industry, and uses the Malmquist index to dynamically analyze the changes in green development efficiency. The empirical results show that the green development level and benefits of the chemical industry in Gansu Province are far from the optimal level, but are increasing year by year. Technological efficiency and technological progress work together in green efficiency.

**Keywords:** Green Development · Super-Efficiency SBM Model · Chemical Industry · The Malquisit Index

## 1 Introduction

Facing China's development goal of "carbon peaking and carbon neutrality", the concept of green development runs through the full text of the "14th Five-Year Plan". Green development means that all entities should pay attention to greening in the development process, adopt green development methods to achieve economic development, and evaluate their green performance in a timely manner [5]. The chemical industry is a traditional industry dominated by fossil energy processing, which penetrates into all aspects of social life, and its carbon emissions should not be underestimated. The carbon dioxide emitted by its production process accounts for about 4% of the national carbon emissions and about 10.2% of the industrial carbon emissions [6]. From the national data, the proportion of the chemical industry is not high. However, from a regional perspective, the industrial structure, energy structure, and energy intensity of each region are significantly different, and the carbon emission per unit income of the chemical industry is higher than the average level of the industrial industry. From the perspective of


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carbon emission intensity, there are significant regional differences in the green development of the chemical industry [2]. Gansu Province is rich in coal and oil reserves. After years of development, Gansu's coal chemical industry has formed three major product series: synthetic ammonia, coking chemical industry, and acetylene chemical industry, and has cultivated a large number of key backbone enterprises such as Jingmei Group, Jinchang Chemical Industry, and Yongxin Group. Gansu province actively promotes the green transformation of chemical enterprises, develops clean energy, adjusts the industrial structure, and promotes industrial clusters under the dual pressure of economic development and green development.

## 2 Literature Review

From the perspective of evaluation methods, [7] have constructed an index system from four dimensions: resource utilization, environmental impact, ecological conservation, and economic benefits, and used the entropy weight TOPSIS combination model to evaluate the green development of agriculture in Jiangxi Province. [1] have selected the SPA-TOPSIS coupling model to comprehensively evaluate the green industrial growth of 15 sub-provincial cities. [4] has used the DEA-RAM model to assess the green development efficiency of the coal industry. [3] has used the Super-SBM model and the Malmquist index model to evaluate the efficiency of green industrial development in Guangdong Province.

## 3 Materials and Methods

This paper takes the chemical industry of Gansu province as the research object and uses the method of analytic hierarchy process to measure the green development level of the chemical industry in Gansu province by means of questionnaire survey and expert review. At the same time, the green development efficiency and total factor productivity index of the chemical industry in Gansu Province were calculated by using the Super-SBM model and Malmquist index model including unexpected outputs, and analyzed from static and dynamic perspectives.

### 3.1 Index System Construction

This paper finally selects the green development performance of the chemical industry as the target layer, the development efficiency, environmental friendliness, and technological high-tech as the criterion layer, and 5 indicators such as cost optimization, environmental protection, green energy saving, innovative development, and technological transformation. The indicator layer is based on total output value, main business income, main business cost, total profit, exhaust gas emission per unit output value, wastewater discharge per unit output value, energy consumption per unit output value, coal consumption per unit output value, and electricity consumption per unit output value. 15 indicators such as the number of R&D personnel, the full-time equivalent of R&D personnel, the R&D expenditure, the number of patents, the expenditure on green technology transformation, and the income from green technology transformation are the sub-index layers, so as to build an evaluation index system for the green development of the chemical industry.

### 3.2 Judgment Matrix Construction

After establishing the green development performance evaluation index system in the chemical industry, this paper uses the AHP to determine the weights of the indicators at each level of the evaluation index system. It makes corresponding questionnaires according to the specific operation steps of the AHP. Experts, scholars, business executives, heads of relevant government departments, and other authoritative persons who have in-depth research in the fields of environmental friendliness and high-tech technology will be scored, and the judgment matrix of each level will be determined from top to bottom according to the expert scores. The eigenvectors of each level are normalized, and the judgment matrix of each level passes the consistency test to obtain the weight of each index of the sub-index layer through the total sorting of the levels. The weight of each indicator is shown in Table 1.

**Table 1.** Weights of indicators for performance evaluation of green development in chemical industry.

| First-level Indicator (A) | Second-level Indicators (B) | Three-level Indicator (C) | Composite layer |
|---|---|---|---|
| Efficient Development(A1) (0.074) | Cost Optimal(B1) (0.074) | Gross output value C1 (0.293) | (0.021) |
| | | Main business income C2 (0.187) | (0.027) |
| | | Main business cost C3 (0.412) | (0.03) |
| | | The total profit C4 (0.108) | (0.008) |
| Environmental friendliness (A2) (0.286) | Environmental Protection(B2) (0.33) | Wastewater discharge per unit of output value C5 (0.5) | (0.047) |
| | | Exhaust emissions per unit of output value C6 (0.5) | (0.047) |
| | Green Energy (B3) (0.67) | Energy consumption per unit of output value C7 (0.633) | (0.121) |
| | | Coal consumption per unit of output value C8 (0.261) | (0.05) |
| | | Electricity consumption per unit of output value C9 (0.106) | (0.0203) |

(*continued*)

**Table 1.** (*continued*)

| First-level Indicator (A) | Second-level Indicators (B) | Three-level Indicator (C) | Composite layer |
|---|---|---|---|
| High-tech (A3) (0.643) | Innovative development (B4) (0.8) | Number of R&D personnel C10 (0.154) | (0.078) |
| | | Full-time equivalent of R&D personnel C11 (0.154) | (0.078) |
| | | Spending of R&D C12 (0.627) | (0.31) |
| | | Number of patents C13 (0.064) | (0.033) |
| | Technological transformation (B5) (0.2) | Expenditure on green technology transformation C14 (0.333) | (0.043) |
| | | Income from green technology transformation C15 (0.667) | (0.086) |

### 3.3 Super-SBM Model

The Super-SBM model has both the ability to solve the slack and the inconsistency problem caused by the traditional DEA model. So his paper uses the Super-SBM model to measure the efficiency of industrial green development rate value.

$$\rho = \mathrm{Min}\theta = \frac{\frac{1}{\mathbf{m}}\sum_{\mathbf{i}=1}^{\mathbf{n}} \overline{\mathbf{x}}_{\mathbf{i}}/\mathbf{x}_{\mathbf{i}0}}{\frac{1}{\mathbf{s}}\sum_{\mathbf{r}=1}^{\mathbf{s}} \overline{\mathbf{y}}_{\mathbf{r}}/\mathbf{x}_{\mathbf{y}0}} \tag{1}$$

$$\mathrm{s.t}\begin{cases} \overline{\mathrm{x}} \geq \sum \gamma_{\mathrm{j}}\mathrm{x}_{\mathrm{j}};\ \overline{\mathrm{y}} \leq \sum \gamma_{\mathrm{j}}\mathrm{y}_{\mathrm{j}};\ \sum \gamma_{\mathrm{j}} = 1 \\ \overline{\mathrm{x}} \geq \mathrm{x}_0, \overline{\mathrm{y}} \leq \mathrm{y}_{0,}\overline{\mathrm{y}} \geq 0, \gamma \geq 0 \end{cases} \tag{2}$$

In the model, the $\rho$ represents the efficiency value, m and s respectively represent the number of input factors and output factors, and $\gamma$ is the weight vector. The larger the $\rho$ value, the higher the green development efficiency of the chemical industry in Gansu Province.

### 3.4 Malmquist Index

The development of things is long-term, the Super-SBM model can only measure the efficiency value of a certain time node. At present, the Malmquist index is widely used in the dynamic analysis of productivity in industry and agriculture. This paper uses the Malmquist index to analyze and decompose the dynamic changes of the green development efficiency of the chemical industry in Gansu Province from 2006 to 2018, which makes the calculation results more scientific.

# 4 Results and Discussion

## 4.1 Data Sources

The relevant data come from the "China Economic Statistical Yearbook" (2006–2018), the "Industrial Economic Statistical Yearbook" (2006–2018) and the statistical yearbooks of various provinces and cities.

## 4.2 Overall Analysis of Green Development Level

According to the calculation results, most of the provinces with a high level of green development in the chemical industry are located in economically developed Guangdong, Jiangsu, Zhejiang, Shandong, Fujian, Anhui, and other provinces in 2018. Among them, Guangdong Province has the highest level of green development, with a green development level of 0.7. The green development of the chemical industry in Gansu Province is 0.24, ranking 15th among 25 provinces and cities, which is at the lower middle level. Judging from the calculation results, there is still a gap between Gansu Province and the optimal national level, mainly as follows: First, the green development efficiency of the chemical industry is not high, and the understanding of cost optimization is lacking. Second, the awareness of environmental protection is not strong. There is a lack of energy-saving and environmental protection measures; third, there is insufficient investment in technological innovation and a lack of green development momentum.

## 4.3 Detailed Analysis Green Development Level

From the perspective of economic benefits, the total output value, leading business income, and total profit of the chemical industry in Gansu Province ranked 22, 22, and 21 in the 25 provinces and cities, respectively. The energy consumption per unit output value, coal consumption per unit output value, and exhaust gas emission per unit output value of the chemical industry in Gansu Province are far from the optimal level. They are in the middle and lower reaches of the entire industry. Judging from the data, energy consumption per unit of output value, coal consumption per unit of output value, and exhaust gas emissions per unit of output value are ranked 15th, 20th, and 19th among 25 provinces and cities nationwide. The number of R&D personnel in the chemical industry in Gansu Province and the investment in R&D funds are downstream of the entire industry and have significant disadvantages. From the data point of view, the number of R&D personnel in the chemical industry and the investment in R&D funds is ranked 18th and 20th among the 25 provinces and cities.

## 4.4 Analysis of Green Development Efficiency

During the ten years, the green development efficiency of the chemical industry in Gansu Province has a good trend of sustainable development and growth. The value of green development efficiency has averaged below 0.73, which is at a lower level. The resource utilization and environmental protection have not yet reached the optimal level of development, indicating that the Gansu province needs to work hard to improve resource utilization in subsequent industrial development and strengthen environmental protection.

### 4.5 Dynamic Analysis of Green Development Efficiency

The Super-SBM model analyzes the green development efficiency of the chemical industry in Gansu Province from a static dimension. In order to better analyze the continuous performance of the green development efficiency, the Malmquist index and DEAP.2.1 software are used to calculate and decompose the dynamic changes of the green development efficiency of the chemical industry in Gansu Province from 2006 to 2018. According to the calculation results of the Malmquist exponential model, From 2006 to 2018, the Malmquist efficiency index of the green development efficiency of the chemical industry in Gansu Province is greater than 1, with an average value of 1.031, indicating that the green development efficiency of the chemical industry in Gansu Province is on the rise and the overall average annual growth rate of industrial green development efficiency is 3.1%.

During the sample study period, the annual average Malmquist Index (ML) in Gansu Province was $1.031 > 1$, the Technical Efficiency Change Index (EC) was $0.977 < 1$, and the Technological Progress Change Index (TC) was $1.055 > 1$. The upward trend is mainly due to the role of technological progress. In different time periods, the changes and causes of green total factor productivity in the chemical industry of Gansu Province are different. After 2013, the green total factor productivity of the chemical industry in Gansu Province has shown an upward trend, mainly due to the simultaneous improvement of technical efficiency and technological progress.

## 5 Conclutions

Through the comprehensive application of the Analytic Hierarchy Process and the TOPSIS method, it is calculated that the green development of the chemical industry in Gansu Province is in the middle and lower level nationwide, and there is still a particular gap with the national optimal development level. The green development efficiency of the chemical industry in Gansu Province calculated by Super-SBM model has a good trend of sustainable development and growth. Resource utilization and environmental protection have not yet reached the optimal level of development. The Malmquist index of green development efficiency is greater than 1, indicating that the green development efficiency of the chemical industry has a good trend of gradual improvement and that technical efficiency and technological progress work together on green efficiency.

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