Analysis of industrial pollution emissions and energy consumption advantages in different regions based on generalized grey relational grade model

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Abstract: With China's economic development entering a new normal characterized by transformation and upgrading, quality improvement and efficiency improvement, the growth rate of GDP has obviously slowed down, and more attention has been paid to the coordinated and sustainable development of economy, society, energy and environment. According to summarizing the research status at home and abroad, this paper focuses on the analysis of industrial pollution emissions, energy consumption (EC) and environment in H province, and introduces the generalized grey relational grade model to calculate the grey relational grade and grey relational matrix between EC and industrial environmental pollution. The important aspects affecting EC and the impact of EC on the environment are analyzed by empirical analysis. Finally, on this basis, the corresponding countermeasures and suggestions to solve the EC and environmental problems in H province are put forward.

1. Introduction

For a long time, human beings have enjoyed the benefits of economic development, social progress, and continuous improvement of scientific and technological level brought by energy consumption (EC), while also bearing the negative impact brought by EC. With the consumption of conventional energy such as coal and oil, energy shortage, environmental pollution and ecological destruction have followed. EC and environmental problems are two major factors that influence and limit the sustainable development of economy and society. "Made in China 2025" pointed out that one of the basic policies for upgrading and developing the manufacturing industry is green development, that is, insisting on sustainable development as an important focus of building a manufacturing power, and by 2025, the EC, material consumption and pollutant emissions per unit of industrial added value of key industries will reach the world advanced level. This requires a fundamental change in the traditional development model and a complete decoupling of industrial growth from resource consumption and environmental pollution.

At present, scholars at home and abroad have made many positive and beneficial explorations on "energy-environment-economy". However, due to differences in measurement methods, time span and research scope, there are still differences in research results [2]. Literature [3] uses panel data analysis method to study the influence of coal consumption on industrial pollution emissions in China. The results show that coal consumption has different impacts on different pollutants, but overall, coal consumption has the most significant impact on exhaust emissions. Literature [4] analyzes the correlation between EC and carbon emissions in the process of China's industrial economic transformation in recent 30 years. The results show that the sustained growth of EC in industrial sectors is the main driving factor for the growth of China's total EC and carbon emissions.

Grey relational analysis is an important part of grey system theory [5], which is a mathematical model to study the degree of correlation between internal factors of the system. The main contribution of this study is based on the generalized grey relational grade model, considering the impact of heterogeneity of EC and industrial pollution emissions in different industries on economic growth, and providing theoretical data support for reasonably determining the direction of industrial structure adjustment and developing energy-saving economy.

2. Energy consumption in China

2.1. China's energy supply is increasing year by year

From 2007 to 2019, China's total energy production showed an upward trend as a whole. Among them, in 2010, China's total energy production was 3.121 billion tons of standard coal, an increase of 9.09% year-on-year, the largest increase in recent years; In 2016, it decreased from the previous year to 3.46 billion tons of standard coal. In 2018, the total energy production was 3.77 billion tons of standard coal, up 5% year-on-year. In 2019, China's total energy production was 3.97 billion tons of standard coal, up 5.31% year-on-year, continuing the growth trend and reaching the highest growth rate in recent 8 years (Figure 1).
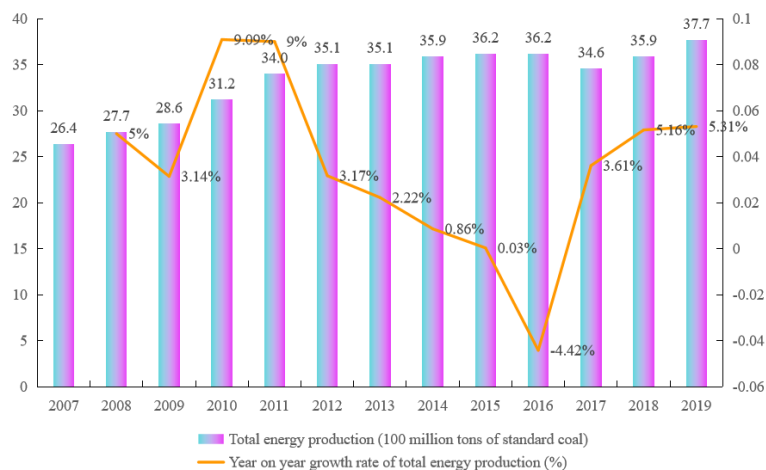

Figure 1 China's total energy production and year-on-year growth rate from 2007 to 2019 (Source: National Bureau of Statistics)

From the perspective of China's energy production structure, in 2018, the raw coal output was 2.613 billion tons of standard coal, accounting for 69.30%, occupying the dominant position of China's energy output; The output of hydropower, nuclear power and wind power is 679 million tons of standard coal, accounting for 18% (Figure 2).
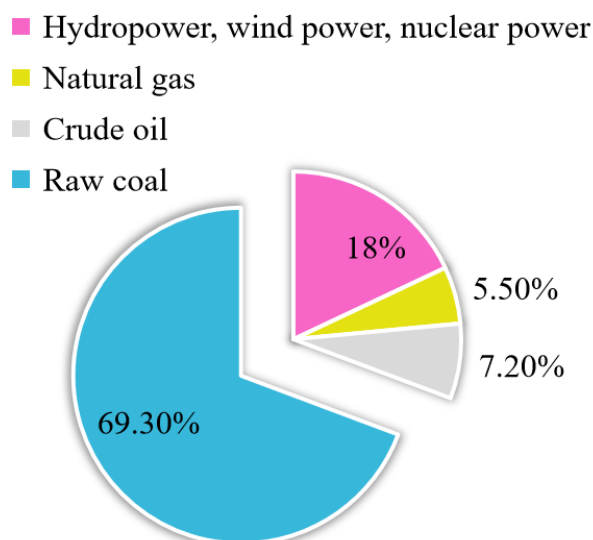

Figure 2 China's energy output structure (Source: National Bureau of Statistics)

2.2. China's energy efficiency has improved

Energy utilization efficiency can be reflected from EC per unit GDP and correlation coefficient. From 2014 to 2019, China's EC per unit GDP decreased year by year, which means that China's energy utilization efficiency increased year by year. In 2019, China consumed 0.49 tons of standard coal per 10,000 yuan of GDP, which was 4.84% lower than that in 2018 (Figure 3).
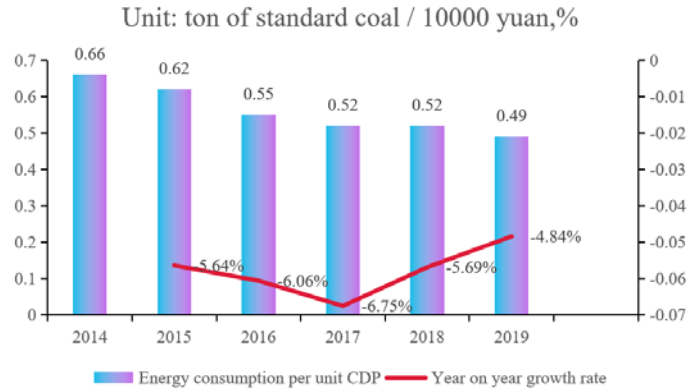
Figure 3 Changes of China's EC per unit GDP in 2014-2019 (Source: National Bureau of Statistics)

Elasticity coefficient of EC is the ratio of the annual average growth rate of EC to the annual average growth rate of national economy, which can show the relationship between national economic development and EC to a certain extent. From 2014 to 2019, China's EC elasticity coefficient first decreased and then increased. In 2019, the elastic coefficient of China's EC was 0.77, which was larger than that in 2018, but lower than 1, indicating that the growth rate of China's EC was lower than that of China's national economy (Figure 4).
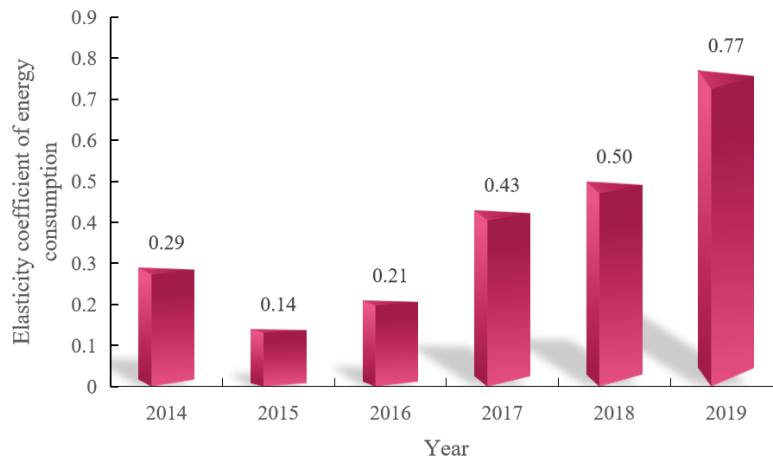

Figure 4 Elasticity coefficient of China's EC from 2014 to 2019 (Source: National Bureau of Statistics)

3. Generalized grey relational grade model

Considering the continuity of statistical caliber, only 10-year time series data can be obtained, so it is not suitable to adopt the analysis method requiring large samples [6]. Therefore, this paper adopts grey relational analysis which has no strict requirements on sample size and data distribution.

The closer the geometric curve shape of the sequence is, the higher the correlation degree between factors is [7]. This method studies the relationship between absolute or relative increments of two sequences, and measures the correlation between the factors represented by two sequences by the area sandwiched between the polylines corresponding to the two sequences. Generalized correlation degree includes grey absolute correlation degree, grey relative correlation degree and grey comprehensive correlation degree. This kind of correlation analysis can not only reflect the similarity between polylines, but also reflect the closeness of the change rate relative to the initial point, which is a comprehensive indicator of the close relationship between reaction sequences [8].

Assuming that X_i and X_j are system behavior sequences with the same length, and their

observation data at the time of serial number k or k are $x_i(k), x_j(k)$ respectively, their grey absolute correlation degree ε_{ij} is given by the following formula:

$$\varepsilon_{ij} = \frac{1 + |s_i| + |s_j|}{1 + |s_i| + |s_j| + |s_i - s_j|} \quad (1)$$

Among them,

$$s_i = \left| \sum_{k=2}^{n-1} x_i^0(k) + \frac{1}{2} x_i^0(n) \right| \quad (2)$$

$$s_j = \left| \sum_{k=2}^{n-1} x_j^0(k) + \frac{1}{2} x_j^0(n) \right| \quad (3)$$

$$x_i^0(k) = x_i(k) - x_i(1)$$
$$x_j^0(k) = x_j(k) - x_j(1)$$
$$k = 1, 2, \cdots, n \quad (4)$$

$0 < \varepsilon_{ij} \leq 1$, the more similar X_i and X_j are in geometry, the greater ε_{ij} is.

Comprehensive correlation degree of X_i and X_j is:

$$\rho_{ij} = \theta \varepsilon_{ij} + (1 - \theta) r_{ij}, \theta \in [0,1], \rho_{ij} \in [0,1] \quad (5)$$

Grey comprehensive correlation degree is an index that comprehensively reflects the tightness between sequences. Generally, θ can be taken as 0.5. If you pay more attention to the absolute correlation degree, the θ is larger; If the grey relative correlation degree is considered seriously, then θ is taken as smaller. In this paper, take 0.5. The closer ρ_{ij} is to 1, the greater the correlation between X_i and X_j.

4. Empirical analysis

4.1. Analysis of the impact of EC on environment

The statistical yearbook of H province, the annual environmental statistics report of H province and the input-output table of H province provide empirical data for this model. In the process of EC, a large amount of waste water, waste gas and solid waste will inevitably be produced, thus causing environmental pollution. The purpose of this paper is to study the impact of EC on environmental pollution in H province, and get the specific damage degree of EC to the environment. Because there is a problem that different units cannot be weighted, the data of these six indicators should be standardized first. The standardized EC data and comprehensive environmental indicators are analyzed by cointegration.

We define G as the comprehensive environmental index, E as the total EC, and use the two index data from 2010 to 2019 for analysis. Firstly, the unit root test of two series data (taking logarithm) is carried out. The ADF test value of variable D(LNE,2) with neither intercept term nor trend term is -2.7342, which is less than the critical value of 5% and 10% significance level, so it can be considered that the second-order difference of LNE is stable. The ADF test value of the corresponding variable D(LNG,2) under the same condition is -6.0279, which is less than the critical value under three significance levels, so the second-order difference of LNG is also stable, and the two variables are stable in the same order. Then use EG test method to carry out

cointegration regression and cointegration test, and get:

$$LNG = -0.0871 + 0.7362LNE + e_t$$
$$R^2 = 0.8266$$

Because R^2 is not close to 1, the fitting degree of this regression is not high, so it is necessary to correct the error of this regression, and VAR model-vector autoregressive model is adopted. The regression obtained after error correction is as follows:

$$LNG = -0.3582LNG(-1) + 0.0893LNG(-2) + 0.04367 + 0.6017LNE + e_t$$
$$R^2 = 0.9685$$

At this time, $R^2 = 0.9685$ is close to 1, and the fitting degree of this regression is very good. From the coefficient point of view, the total EC has a great impact on the environment. If the EC increases by 1 percentage point, the environmental comprehensive index will increase by 0.6017 percentage points, and if it is equal, the six major indicators of industrial pollution will increase by 0.6017 percentage points. It can be seen that for a long time, the EC in H province is an important cause of environmental pollution and has an important influence on the quality of the environment.

4.2. Advantage analysis of EC and industrial environmental pollution

Advantage analysis is a kind of grey relational analysis. When there are more than one reference series and more than one factor to be compared, the relational analysis is called advantage analysis. At present, there are many kinds of EC, including coal, oil, natural gas, hydropower, nuclear power, wind power, solar energy and biomass energy. According to the data of the Statistical Yearbook of H Province from 2010 to 2019, the original data is sorted out. Taking the data of 2009 as the reference series, according to the grey relational analysis method, the grey relational matrix R_{ij} is obtained as follows:

$$R_{ij} = \begin{bmatrix} 0.7366 & 0.5981 & 0.7725 \\ 0.5682 & 0.7015 & 0.8830 \\ 0.6893 & 0.8056 & 0.8259 \\ 0.6634 & 0.6729 & 0.9274 \end{bmatrix}$$

It can be seen from R_{ij} that $R_{43} = 0.9274$ is the largest among all elements, indicating that the discharge of industrial solid waste has the greatest correlation with the use of clean energy, which is the basis for China and even the whole world to vigorously advocate the use of clean energy in order to reduce pollution and achieve sustainable development.

5. Policy advice

Through the above empirical analysis, it can be seen that the industrial pollution emission in the industrial panel increases with the increase of EC. In addition, there is a significant nonlinear relationship between economic growth and industrial pollution emission, which shows that industry can solve the problem of environmental degradation through its own economic development. In the industrial industry, most industries have significant influence of EC on industrial pollution emissions; however, the nonlinear relationship between economic growth and industrial pollution emission is inconclusive. This paper puts forward the following policy suggestions:

5.1. Adjust the industrial structure

We should pay attention to the strategic upgrading of industrial structure in H province, control the proportion of industries with high EC and high pollution, rationally plan the industrial layout, and achieve the goal of saving energy and reducing consumption through industrial structure

adjustment. Due to the abundant energy resources in H Province, the characteristic industries and key industries of extractive industry and raw material industry formed by relying on resources should continue to strengthen their development, but more attention should be paid to the quality of the development of these characteristic industries. In addition, through the development of communication equipment, computer and other electronic equipment manufacturing industries, these are not only conducive to the information development of H Province, but also more conducive to the rationalization of industrial structure and environmental protection.

5.2. Development and Utilization of New Energy

The development and utilization of new energy, especially renewable energy, is an important guarantee to realize sustainable economic development in H province. These energy sources are not only abundant in reserves, but have no or very little impact on the environment. However, the development and utilization in this area in H province is far from enough, and they will be the basis of EC in H province in the future. The development and utilization of renewable energy is the core of sustainable energy development in H province, which requires strategic planning and deployment. The government should implement incentive policies to promote the development and utilization of renewable resources, and introduce and adopt high and new technologies to improve energy utilization efficiency.

5.3. Increase environmental protection efforts

Implementing an environment-friendly energy strategy needs to correctly handle the relationship between energy and environment, and environmental protection will be considered as the main content of energy strategy decision. This strategy requires the government to drive, the public to participate, and the exact indicators to control. Enterprises and individuals should change their concepts and form certain environmental awareness, so that the work of environmental protection really falls on everyone, and energy conservation starts from you and me.

6. Conclusions

In this paper, on the basis of drawing lessons from relevant energy and environmental research at home and abroad, the impact of EC on the environment in H province is analyzed. The conclusions of this paper are as follows:

(1)The regression coefficient of total EC and total environmental pollution index in H province reaches 0.6017, and with the increase of EC by 1 percentage point, the environmental pollution indexes will increase by 0.6017 percentage points accordingly. In the EC structure of H province, the consumption of coal, oil and electricity has a great impact on the environment, and the most serious environmental pollution is the consumption of electricity. If the EC structure is optimized accordingly, the emissions of various pollutants can be reduced accordingly.

(2)There is a significant correlation between EC and industrial environmental pollution. To reduce industrial environmental pollution, it is necessary to reduce the use of traditional energy, vigorously develop clean energy and improve energy efficiency.

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