Research on Emission Reduction Pressure of Key Industries under Carbon Quota Constraint

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Abstract

Under the background of increasing global energy shortage and environmental pollution, the emission reduction pressure of industrial key industries is studied. First, the main carbon emission industry in industry is screened out by Pareto criterion. Secondly, through the Grey correlation analysis, key industries are identified from the major carbon emission industries. Thirdly, based on the GM (1,1) model and the "historical carbon emission preference" quota scheme, the key industry emission reduction pressure in 2020 has been calculated. The Coal Mining and Washing industry, Ferrous Metal Smelting and Processing industry and Electricity Heating Production and Supply industry are all faced with significant emission reduction pressure, which should be the focus of follow-up carbon emission management.

Keywords

Key industries; carbon emission quota; carbon emission prediction; emission reduction pressure.

1. Preface

As the world's largest developing country and the second largest energy producer and consumer, China's environment and energy issues have always been accompanied by China's economic development. In 2016, the executive meeting of the state council formulated the action target of China's annual greenhouse gas emission control: by 2020, China's carbon dioxide emissions per unit of GDP will be 18% lower than that of 2015. China's industrial industry has a high contribution to GDP and carbon emissions. In order to achieve the goal of energy conservation and emission reduction, industry is the key point. Industry with high output value and large emission is the most important. Key industries have been identified, and analysing the pressure to reduce emissions is crucial to ensuring the achievement of emission reduction targets.

Carbon emission reduction has been widely studied by domestic and foreign scholars. This paper reviews the perspectives of carbon emission quota and carbon emission forecasting. In terms of carbon emission quota research, Wu and others use the improved DEA model to verify the fairness and efficiency of the carbon emission distribution mode[1]. Carbon emission quota is allocated by Wei and others from the perspective of fairness and efficiency[2]. According to the environmental technology economics and environmental learning curve (ELC), the carbon emission reduction potential of 30 provinces is predicted by Sun Gennian[3]. By constructing the carbon emission factor decomposition model of China petrochemical industry, Grey prediction theory and scenario analysis are used by Li Xiaopeng to simulate the influence of carbon trading system on petrochemical industry[4]. In terms of carbon emission prediction, Based on the Kaya formula, combined with Waxman-Markey and Obama policy objectives, three scenarios are set by Lester and others to predict carbon emissions[5]. Cromptonfw predicted the total energy demand of China based on Bayesian method[6]. The Grey Correlation Prediction method is used by Shen Xiaoyan to predict the energy consumption of our country in the past 2010-2015 years[7]. Based on 2005, Yue Chao and others predicted China's carbon emissions by 2050[8].

To sum up, carbon emission quota and carbon emission prediction are widely studied by scholars, but there is still room for improvement in research objects and methods. First of all, in the selection of

research objects, scholars have studied carbon emission related issues from the perspective of national or regional perspectives, and have not yet found out the systematic study of carbon emission in the whole industry. Secondly, in terms of carbon emissions quota research, Scholars have used one of the principles for the allocation of carbon emission quota, such as the principle of fairness, efficiency and the historical responsibility. The research on the allocation of carbon quota by combining several principles is seldom seen. This is the opportunity of this research. This paper takes industry as the object of study, and grey correlation forecasting technology is used to identify key industries from the perspective of carbon emission and output value. In combination with the actual situation, the "cumulative principle of historical carbon emission" and "GDP principle" are given different weights to allocate quotas to key industries the profit and loss status of the key industry carbon quota is analyzed.

2. Identification of the industry's major carbon emissions industry

The annual CO_2 emissions from the atmosphere are usually caused by an energy combustion, industrial waste gas emissions, natural activities and daily life of residents. This paper mainly studies CO_2 emission caused by fossil energy consumption.

(1)Measurement of industrial carbon emissions in 2005-2015

Based on the annual statistics, the industrial sector is divided into 39 industries according to the statistical yearbook. The emission factor method proposed by IPCC is used to calculate the carbon emissions of 39 industries for 2005-2015 years by converting the consumption of coke, coal, gasoline, crude oil, diesel oil, kerosene, fuel oil and natural gas into standard coal and then combining carbon emission coefficient. The proportion of total industrial carbon emissions to total industrial emissions is calculated. The final account is Fig.1.

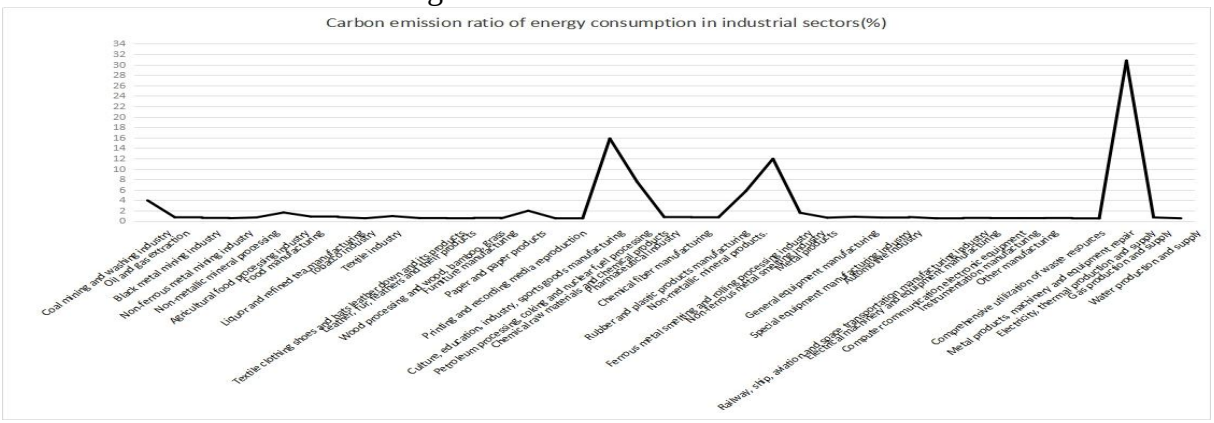

Fig.1 Carbon emission ratio of energy consumption in industrial sectors

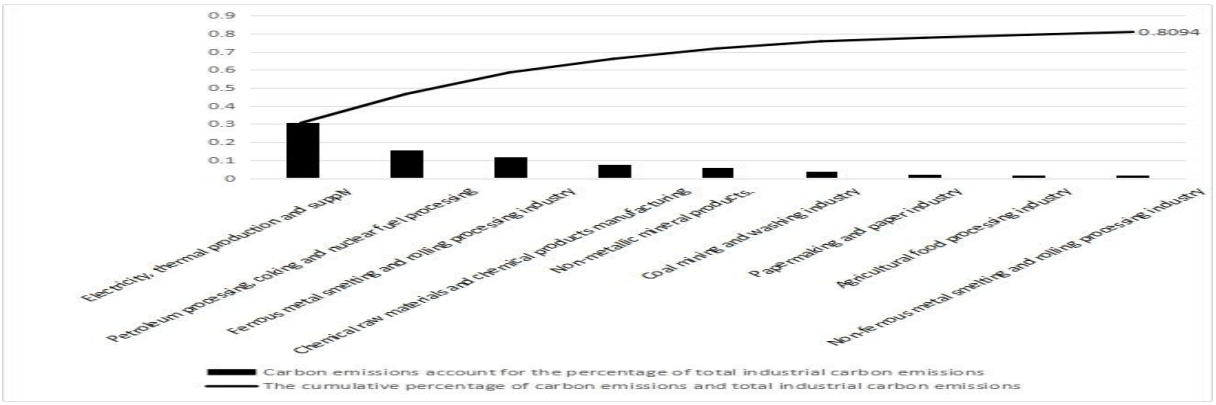

Fig.2 The Pareto curve of Industry account for Total industrial carbon emissions.

(2)Characteristics of industrial carbon emissions

Due to the large difference of carbon emissions between industries, Pareto law is used to calculate the ratio of the total industrial and industrial emissions. The industry with a ratio of more than 80% is defined as the major industry that affects industrial carbon emission, and the distribution diagram of major industries is obtained (Fig.2).

3. Identification of key industrial industries

Key industries have different connotations at different times and different methods of division in specific periods. The leading sector is regarded by people like Kang Kai as the key sector[9]. The Virtual elimination Method (VEM) is adopted by Chen Xiaozhen, and identifies the key industries by means of Weaver-Thomas index [10]. The key industries are newly defined by this paper, that is, industries with high energy consumption, high emission and high output value.

In the identified major carbon emission industries, the Grey relational analysis method is adopted to identify key industries based on the research method of Jiang Shengsheng[11]. In which, Grey absolute correlation(ε_{0i}) refers to the similarity between parent sequence X_0 and comparison sequence X_i. Gray relative correlation(γ_{0i}) refers to the degree of correlation between X_0 and X_i relative to the initial point. Comprehensive correlation(ρ_{0i}) refers to the synthesis of ε_{0i} and γ_{0i}. The length of X_0 and X_i are assumed to be consistent, and their initial value is not zero. Making $\theta \in [0,1]$, in the current academic research, the assignment of θ is usually 0.5, and ρ_{0i} is calculated.

$$\rho_{0i} = \theta\varepsilon_{0i} + (1-\theta)\gamma_{0i} \quad (1)$$

Using Grey relational analysis theory and Grey-Modeling 3 software, the grey correlation between the output value of 9 carbon emission industries and carbon emissions is calculated(Tab.1). Among them, the output value of carbon emissions comes from 2005~2016 "China Statistical Yearbook". In order to eliminate the impact of inflation and other price factors, the average value of the consumer price index and the retail price index of commodity is used to reduce the comparable value of the comparable value of each industry in 2005.

Tab.1 Key industry correlation coefficient.

Industry	ε0i	γ0i	ρ0i
Coal mining and washing industry	0.88	0.99	0.94
Agricultural food processing industry	0.51	0.82	0.67
Papermaking and paper industry	0.56	0.81	0.69
Petroleum processing, coking and nuclear fuel processing	0.81	0.94	0.88
Chemical raw materials and chemical products	0.68	0.87	0.77
Non-metallic mineral products.	0.64	0.84	0.74
Ferrous metal smelting and rolling processing industry	0.80	0.90	0.85
Non-ferrous metal smelting and rolling processing	0.61	0.96	0.79
Electricity, thermal production and supply	0.89	0.84	0.86

Combined with the Tab.1, the overall correlation of the 6 industries is more than 0.75. The carbon emissions and industrial output value of these industries are shown to have a strong correlation and are identified as the key industries.

4. Carbon emission prediction in key industrial industries

(1)The principle of GM (1,1) model

Set the original sequence, $X^0 = \{x^0(i)\}(i = 1,2,\dots,n)$, a non-negative monotone original data column for a certain prediction object. First, the first order accumulation of X^0, is 1-AGO. An accumulation sequence(albino sequence) is generated,

$$X^{(1)} = \left\{x^{(1)}(1), x^{(1)}(2), \dots x^{(1)}(n)\right\} = \left\{x^{(1)}(k), k = 1,2,\dots,n; n \geq 4\right\}, \quad (2)$$

In which,

$$x^{(1)}(k) = \sum_{i=1}^{k} x^{(0)}(i) \quad (3)$$

For $x^{(1)}(k)$, a differential equation with the following whitening form can be established, namely GM (1,1) prediction model,

$$\frac{dX^{(1)}}{dt} + aX^{(1)} = b \quad (4)$$

The solution of the above albino differential equation is,

$$\hat{X}^{(1)}(k+1) = \left[X^{(0)}(1) - \frac{b}{a}\right]e^{-ak} + \frac{b}{a}, (k = 1,2,\dots,n-1) \quad (5)$$

Finally, GM(1,1) can be obtained by subtraction,

$$\hat{X}^{(0)}(k+1) = \hat{X}^{(1)}(k+1) - \hat{X}^{(1)}(k) = (1 - e^{a})\left[X^{(0)}(1) - \frac{b}{a}\right]e^{-ak}, \quad (k = 0,1,2,\dots,n) \quad (6)$$

(2)GM (1,1) model test.

The accuracy of the GM (1,1) model can be determined by the posterior difference ratio C and the small error probability P. The smaller the C, the larger the P, the higher the prediction accuracy. According to the size of C and P, the prediction accuracy is divided into one, two, three and four grades, among which the prediction accuracy is the highest.

(3)Prediction of carbon emission in key industries

The carbon emission of key industries from 2005-2015 is the original sequence, and GM (1,1) is established, then the Grey prediction program is prepared by using MatlabR2014a software to predict the carbon emission in the future years. Due to space limitations, only the prediction equation (equation (7)-(12)), the test results (Tab.2, column 8) and the forecast of carbon emission from 2016-2020 (Tab.2 column 2~7) are listed.

$$\hat{X}^{(0)}(t) = 30291.2 * e^{0.07(t-2005)} \ (t = 2006,2007,\dots 2020) \quad (7)$$

Coal mining and washing industry,

$$\hat{x}^{(0)} \cdot (k+1) = 7329.4 \times e^{0.11(t-2005)} \ (t = 2006,\cdots 2020) \quad (8)$$

Chemical raw materials and chemical products manufacturing,

$$\hat{x}^{(0)} \cdot (k+1) = 18901.19 \times e^{0.08(t-2005)} \ (t = 2006,\cdots 2020) \quad (9)$$

Non-ferrous metal smelting and rolling processing industry,

$$\hat{x}^{(0)} \cdot (k+1) = 1440 \times e^{0.21(t-2005)} (t = 2006,\cdots 2020) \quad (10)$$

Electricity, thermal production and supply,

$$\hat{x}^{(0)} \cdot (k+1) = 63493.15 \times e^{0.07(t-2005)} \ (t = 2006,\cdots 2020) \quad (11)$$

Petroleum processing, coking and nuclear fuel processing,

$$\hat{x}^{(0)} \cdot (k+1) = 14389.93 \times e^{0.09(t-2005)} \ (t = 2006,\cdots 2020) \quad (12)$$

Tab. 2 Key industry carbon emission gray forecast result in 2016-2020（Unit: million tons.）

Industries	2016	2017	2018	2019	2020	精
Coal mining and washing industry	257.0	287.9	322.6	347.2	385.2	1
Petroleum processing, coking and nuclear fuel	778.2	794.3	810.8	833.0	855.0	1
Chemical raw materials and chemical products	432.0	469.9	517.6	570.4	626.6	2
Ferrous metal smelting and rolling processing	634.7	681.0	730.6	783.9	841.1	1
Non-ferrous metal smelting and rolling processing	113.2	133.5	150.6	176.1	212.0	1
Electricity, thermal production and supply	1231.	1261.	1281.	1346.	1365.	1

5. Analysis of emission reduction pressure of industrial key industries

(1)Carbon quota model construction

At present, the principle of carbon quota includes fairness principle, benefit principle, historical responsibility principle and so on. In view of the high output value and high emission characteristics of industrial key industries, the principle of fairness and historical responsibility are selected for the key industries. The principle of equity in a certain industry should be proportional to its contribution to the national economy, that is, the GDP principle; the principle of historical responsibility refers to the proportion of carbon quotas in a certain industry to the proportion of the cumulative carbon emissions at a certain stage to the total carbon emissions in the country. The carbon quota model of key industries is put forward.

$$C_i = \frac{\sum_t G_i}{\sum_t G_j} \times C_w \times \alpha + \frac{\sum_t Q_i}{\sum_t Q_j} \times C_w \times \beta \quad (13)$$

In which, The carbon emission quota obtained by a certain industry is expressed by Ci. The total gross product of i industry in a certain period of time is expressed in Gi. Gj represents the total GDP of the whole country, C_w represents the total amount of carbon quota. Q_i represents the cumulative carbon emissions of i during a certain period. Both α and β are weight parameters introduced. α is the weight coefficient of GDP principle, β represents the original weight coefficient of historical responsibility, and the values of α and β represent different quota schemes. α+β=1. The values of α and β represent different quota schemes. Referring to the weight selected by Li Xiaopeng for the carbon emission quota of petrochemical industry, there are three possible quota schemes[4].

When α=β=0.5, the carbon emission quota is balanced; when α=0.7, β=0.3, the carbon emission quota is a historical emission preference; whenα=0.3, β=0.7, the carbon emission quota is a preference for the level of economic development. Because the key industry is difficult to reduce carbon emissions in a short time, the "historical emission preference" program is adopted.

(2) Key industry carbon quota calculation

China's GDP calculation in 2020. According to the latest data released by Statistics Bureau, the economic growth rate of China in 2015 and 2016 is 6.9% and 6.7% respectively. According to the study of Zhao Xi[12], the economic growth rate of 2017-2020 years is set to 5%, 6%, and 7%, respectively, in terms of low, medium and high, and the base period of 2015 is to measure the 2020 GDP.(Tab.3)

China's carbon dioxide emissions in 2020. According to the calculation, China's carbon dioxide emissions in 2015 totaled 57.9 billion tons, and the carbon dioxide emission intensity was 3.09 tons/ten thousand yuan. On the basis of 2015, in accordance with our target of controlling greenhouse gas emissions in 2020, the carbon dioxide emissions of China's gross domestic product (GDP) fell by 18% in 2020 than in 2015. The carbon intensity should be reduced to 1.7 tons per thousand yuan and 1.85 tons per million yuan by 2020. According to the different GDP growth scenarios from 2016 - 2020, the total amount of carbon dioxide emissions in 2020 will be calculated.(Tab.3)

Tab. 3 The total amount of CO_2 released by China in 2020 under different GDP growth.

GDP growth (%)	Emissions reduction targets(%)	GDP in 2020(1012¥)	Carbon intensity in 2020 (Tons/ten thousand yuan)	Total carbon emission in 2020(108Tons)
5	18	26.85	0.83	49.8
6	18	28.15	0.83	52.21
7	18	29.51	0.83	54.72

(3)Industrial key industry emission reduction pressure calculation

From Tab. 4, China's carbon emission space in 2020 is roughly 49.8 * 10^8t CO_2 to 54.72 *10^8tCO_2. When the GDP growth rate is 5%, the carbon emission space of 2020 will be the smallest and the most difficult to achieve. When GDP is growing at 6%, it is the most likely scenario for the future. The carbon intensity reduction target is 18%, the carbon quota of key industries in 2020 and the profit and loss of carbon emission.

Tab. 4 The profit and loss analysis of the quota of key industries in 2020 at 5%(6%) of GDP growth.（Unit: 10,000 tons）

Industries	Quota	Forecast quantity	Profit and loss	ratio（%）
Coal mining and washing industry	18931.82 (22850.67)	38526.03 (38526.03)	-16594.21 (-15675.36)	-75.66 (-68.60)
Petroleum processing, coking and nuclear fuel processing	57755.44 (84211.59)	85508.09 (85508.09)	-7752.65 (-1296.50)	-9.9 (-1.54)
Chemical raw materials and chemical products manufacturing	58274.97 (61103.33)	62680.01 (62680.01)	-4405.04 (-1576.68)	-7.5 (-2.58)
Ferrous metal smelting and rolling processing industry	73569.23 (72139.90)	84121.44 (84121.44)	-15552.21 (-11981.54)	-22.68 (-16.61)
Non-ferrous metal smelting and rolling processing industry	19697.21 (20653.21)	21207.96 (21207.96)	-1510.75 (-554.75)	-7.67 (-2.69)
Electricity, thermal production and supply	109114.50 (114410.34)	176501.93 (176558.23)	-67443.73 (-62147.89)	-61.81 (-54.27)

In 2020, the deficit will be negative for the carbon emission quota deficit, and the profit and loss will be the surplus of carbon emission quota. The ratio is equal to the ratio of the profit and loss to the quota. The larger the ratio is, the larger the profit or loss is. The industry, with a quota deficit of more than 15 per cent, is a "high pressure" key industry (the shadow font industry in Tab.4)

6. Conclusion

Based on the statistical data from 2005 to 2015, the Grey correlation analysis and prediction theory is used to study the emission reduction pressure of key industries, and come to the following conclusions:

Based on the Pareto criterion, the main carbon emission industry in industry is screened out from the perspective of industry output and carbon emission, and the six key industries are identified by referring to the Grey relational analysis theory, such as Coal mining and washing industry, Petroleum processing, coking and nuclear fuel processing, Chemical raw materials and chemical products manufacturing, Ferrous metal smelting and rolling processing industry, Non-ferrous metal smelting and rolling processing industry, Electricity, thermal production and supply.

Based on the GM (1,1) model, the key industries are predicted to emit carbon emissions from 2016 to 2020. "Historical emissions preference" quota scheme is adopted for each key industrial carbon emissions quotas in 2020. Then the key industries can be divided into two categories. Firstly, in the context of economic growth of 5% and 6%, the industry with a carbon deficit of less than 10% has a

basic carbon footprint. Second, the carbon deficit in 2020 is a serious deficit. It is defined as the "high pressure" key industry. To achieve the goal of energy saving and emission reduction, such key industries need to adopt other energy-saving and emission reduction methods, or to purchase carbon emission rights from industries with carbon emission quota surplus.

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