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Study on Initial Allocation of Carbon Emission Rights in the Middle and Lower Reaches of the Yellow River

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Abstract

In order to provide reference for low-carbon transformation and high-quality development decision-making in the Yellow River Basin, scientific and reasonable allocation of carbon emission rights is of great significance. Considering the principles of fairness, efficiency and sustainable development, this paper constructs the carbon emission right distribution index system in the middle and lower reaches of the Yellow River, including 11 indicators in three aspects. Based on critical method and fuzzy optimization, the corresponding initial allocation model of carbon emission rights is constructed. The grey prediction model is used to obtain the relevant index data of the middle and lower reaches of the Yellow River in 2025, and the model results are compared with other allocation schemes. The allocation scheme comprehensively considers a variety of factors to allocate carbon emission rights, which is more in line with the actual situation of the middle and lower reaches of the yellow river. The model can provide experience for the national allocation of carbon emission rights.

Keywords

Carbon emission quota allocation, CRITC, Grey prediction, Middle and lower reaches of the Yellow River.

1. Introduction

The virus has ravaged the world and the epidemic has been repeated, The COVID-19 will not be the last crisis facing mankind. It has become a global consensus to reduce greenhouse gas emissions and actively respond to climate change. In September 2020, China vowed to the world that carbon dioxide emissions would reach a peak by 2030 and strive to achieve carbon neutrality by 2060[1]. As an important policy tool to promote the realization of the carbon peak goal and the vision of carbon neutrality, the value of carbon emission trading has become increasingly prominent. The Chinese government is also actively promoting and constructing the carbon market mechanism, and has put forward the goal of establishing China's unified carbon trading market by 2020. However, the establishment of carbon emission trading system needs to be based on the initial allocation of carbon emission rights, that is, the carbon emission trading system first obtains the initial carbon emission quota through allocation, and then there is the differentiation of emission surplus and deficiency, which will produce trading. For China, the allocation of carbon emission rights is mostly based on regional equity and industry equity [2,3]. In terms of the rationality of quota allocation, the current quota adopts the industry benchmark method with intensity control as the basic idea, and implements free allocation [4].

On the morning of September 18, 2019, President Xi presided over the Symposium on ecological protection and high-quality development of the Yellow River Basin in Zhengzhou and delivered an important speech[5]. The Yellow River Basin, also known as the 'energy basin', is rich in coal, oil and natural gas resources, and its coal reserves account for more than half of the country. However, with the development of economy, the consumption of resources and the damage to

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the environment are becoming more and more serious. Whether the region can avoid the rapid growth of CO2 emissions has become the focus of attention. The allocation of carbon emission rights in the middle and lower reaches of the Yellow River is to allocate carbon emission rights to each region under the condition of determining the total amount of regional carbon emission rights and comprehensively considering various factors. Study the distribution of carbon emission rights in the middle and lower reaches of the Yellow River, and provide some reference for other key regions in China to achieve carbon emission reduction.

2. Research status

According to international standards, energy can be divided into primary energy and secondary energy. The former is natural energy, which refers to existing energy in nature, such as coal, oil, natural gas, hydropower, etc; The latter refers to the energy products converted from primary energy processing, such as electricity, gas, steam and various petroleum products. The energy structure usually counted by the state mainly refers to coal, oil and natural gas. Through their changes, we can predict and evaluate the energy consumption trend of our country. Figure 1 shows the current situation of energy consumption in the middle and lower reaches of the Yellow River in recent years. Data on energy consumption come from historical statistical yearbooks of each province, and 0 to 5 respectively Inner Mongolia, Shaanxi, Shanxi, Henan, Hebei, Shandong. Among them, Shandong province has the largest energy consumption, which is much higher than other provinces, and increases year by year, and the government is the largest. This may be because Shandong province has many energy advantages, but with the rapid economic growth, the total energy consumption increases rapidly; The energy consumption of Hebei Province ranks second in the middle and lower reaches of the Yellow River, and the government has been slightly larger since 2015 than before 2015; Henan Province, Shanxi Province and Inner Mongolia took the second place, and Inner Mongolia energy increased after 2017; Shaanxi Province has the least energy consumption. But as one of the important energy base of China, Shanxi Province for many years, relying on coal industry development, formed mainly to coal industrial structure and energy consumption structure, economic and social development and is closely related to coal production, consumption, high intensity of coal mining and utilization for a long time in support of the provincial economic and social development at the same time, its energy consumption is increased year by year.

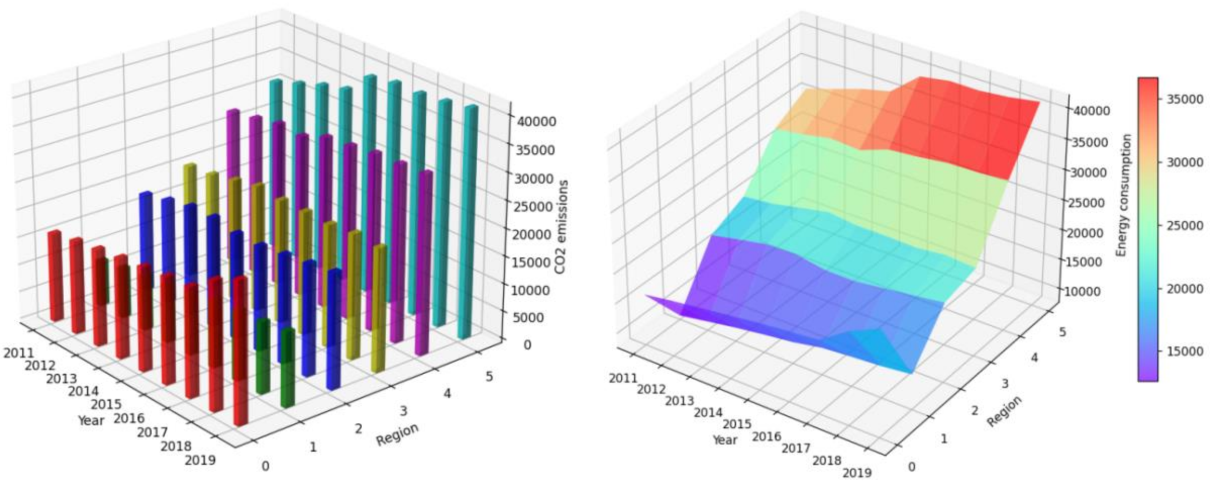

Figure 1: Comparison of primary energy consumption of cities in the middle and lower reaches of the Yellow River from 2011 to 2019

Energy consumption is the main source of CO2 emission. The middle and lower reaches of the Yellow River is an important energy, chemical and basic industrial base in China, with large energy consumption and total carbon emissions. It can be seen from Figure 2, and 0 to 5 respectively Inner Mongolia, Shaanxi, Shanxi, Henan, Hebei, Shandong. Shanxi Province is a province with carbon emission amplification in the middle and lower reaches of the Yellow River, with carbon emission ranking first, but its energy consumption ranking second, which may be due to the lack of low-carbon emission reduction measures; Shandong Province has a rapid economic development and is the pillar of the economy in the middle and lower reaches of the Yellow River. In the process of economic development, it needs to consume a lot of energy and emit a lot of CO2, but the carbon emission remains basically stable. Due to the protective measures in place, even if the energy consumption is the largest, the carbon emission is not the first, which shows the effectiveness of low-carbon emission reduction; Inner Mongolia Autonomous Region has boundless grasslands and rich agricultural, animal husbandry and mining resources. It is a resource-dependent region, which has made outstanding contributions to China's economy, with a carbon emission of about 80 million tons; The carbon emissions of Hebei Province, Henan Province and Shaanxi Province remained basically similar and at a stable level. From 2011 to 2015, the carbon emissions of Hebei Province and Henan Province were slightly greater than that of Shaanxi Province.

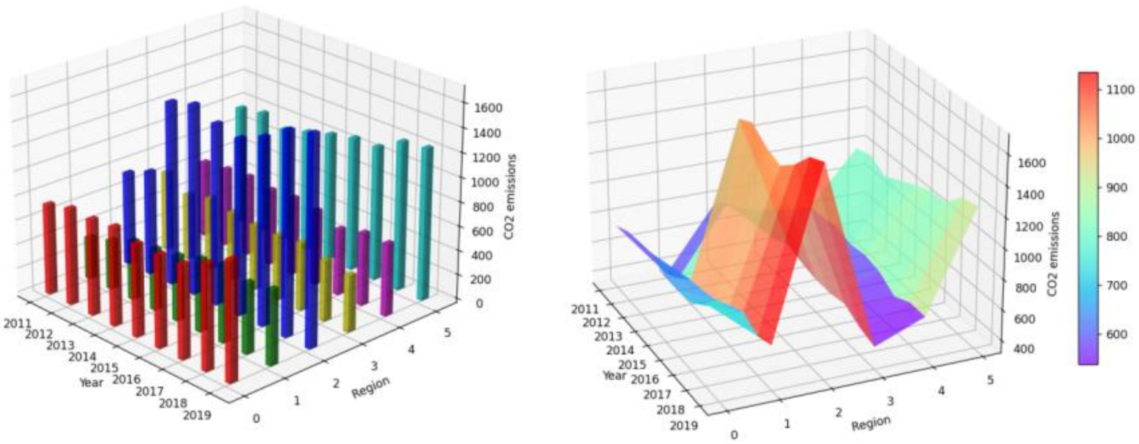

Figure 2: CO2 emissions in the middle and lower reaches of the Yellow River

3. The initial allocation principle and index system of carbon emission rights

3.1. Allocation principle

Whether the allocation of carbon emission rights in the middle and lower reaches of the Yellow River is scientific and effective is related to the success or failure of the carbon emission rights system. Taking the basic allocation principle as the guiding principle to ensure the effective implementation of carbon emission rights allocation and the fairness and effectiveness of the allocation results. At the same time, it plays an important role in realizing the goal of energy conservation and emission reduction and the construction of ecological civilization in the Yellow River Basin. The allocation principle[6] of carbon emission rights has long been discussed and analyzed at a deeper level in the world. They basically follow the principles of fairness and efficiency. However, according to China's basic national conditions, sustainable development is an important principle that must be considered.

3.1.1. The principle of fairness

The principle of fairness[7] is the basis of global climate change negotiations. It is accepted by the international community and plays an important role in establishing the international climate system. The population size, resource endowment and industrialization level of provinces in the middle and lower reaches of the Yellow River vary greatly, and regional economic development varies greatly. Regional differences should be taken into account when formulating various policies. According to the national development policy of "giving priority

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to efficiency and giving consideration to fairness", under the condition of total amount control, the distribution of carbon emission rights in the middle and lower reaches of the Yellow River should be adjusted to local conditions and cross regional compensation should be flexibly used, that is, if the regional environmental capacity is sufficient, Free distribution mode can be selected; If the regional environmental capacity consumption is too large, the paid distribution mode can be selected.

3.1.2. Efficiency principle

Efficiency principle[8] is the principle of optimizing resource allocation. Carbon emission intensity index is mainly used to measure the relationship between a country's economy and carbon emissions, expressed in carbon dioxide emissions per unit of GDP. Therefore, the carbon emission reduction plan in the middle and lower reaches of the Yellow River should make the carbon emission reduction model fair and operable according to the carbon emission intensity index, and set a reasonable baseline of carbon emission intensity, so as to maintain the continuous decline of carbon emission under the rapid economic growth.

3.1.3. Principle of sustainable development

Principle of sustainable development[9] as the right of human development, the allocation of carbon emission rights in the middle and lower reaches of the Yellow River should unswervingly follow the principle of sustainable development. When establishing the greenhouse gas emission allocation mechanism, we should take into account the economic development of various regions, and meet not only the needs of contemporary people, but also the survival needs of future generations. From the perspective of inter provincial equity, the inter provincial development level is unbalanced, and the primary task of backward provinces is still to develop economy and eliminate poverty, but it can not be used as an excuse to fail to achieve the overall national goal. The per capita carbon emissions of economically backward provinces are allowed to be slightly higher than those of other provinces. By gradually reducing carbon emissions, they will reach the level of developed provinces by the target year, which reflects the concept of protecting economically backward provinces and sustainable development and jointly achieve low-carbon emission reduction.

3.2. Distribution index system

The determination of the total amount of carbon emission right is the basis of regional distribution, and the carbon emission mainly comes from the heavy industry with high energy consumption, and the regional forest greening has the capacity of carbon sink. Therefore, the determination of the total amount of carbon emission is determined according to the carbon emission of energy consumption, the carbon emission of cement consumption and the forest carbon sink. The allocation of carbon emission rights at the next level is a multi factor and multi-level systematic project, which considers not only the factors of fairness, but also the principles of efficiency and sustainability, so as to achieve the goal of low-carbon emission reduction .

According to the above distribution principles, build the carbon emission right distribution index system[10] in the middle and lower reaches of the Yellow River, calculate the total amount of carbon emission right in the middle and lower reaches of the Yellow River according to each index, and carry out regional distribution. Table 1 shows it.

Table 1: Index System of carbon emission right distribution in the middle and lower reaches of the Yellow River

Primary index	Secondary index	Tertiary indicators	Company
Allocation of carbon emission	Principle of fairness	Population size	Ten thousand people
		Population growth rate	%

rights in the middle and lower reaches of the Yellow River		Historical regional carbon Emissions	Million tons
		Proportion of secondary Industry	%
		Energy consumption	Million tons
	Efficiency principle	Per capita GDP	Yuan
		Carbon emission intensity	ton/ten thousand yuan
		Energy consumption of Industrial added value	ton/ten thousand yuan
		Energy consumption intensity	ton/ten thousand yuan
		GDP Net outflow	billion
	Principle of sustainable development	Forest coverage	%

4. Materials and methods

4.1. The grey prediction

Gray forecast model[11] (Gray Forecast Model) is a prediction method to establish a mathematical model and make prediction through a small amount of incomplete information. It is an effective tool to deal with the problem of small sample prediction.

The simplest model is GM (1,1), G: Grey; M: Model; (1,1): first order differential equation model with only one variable.

Application conditions of grey prediction: it is used for time period, there are few data, the data does not need typical distribution law, the amount of calculation is low, and it has high accuracy for short-term prediction. It is not suitable for data with large random fluctuation.

4.1.1. Algorithm

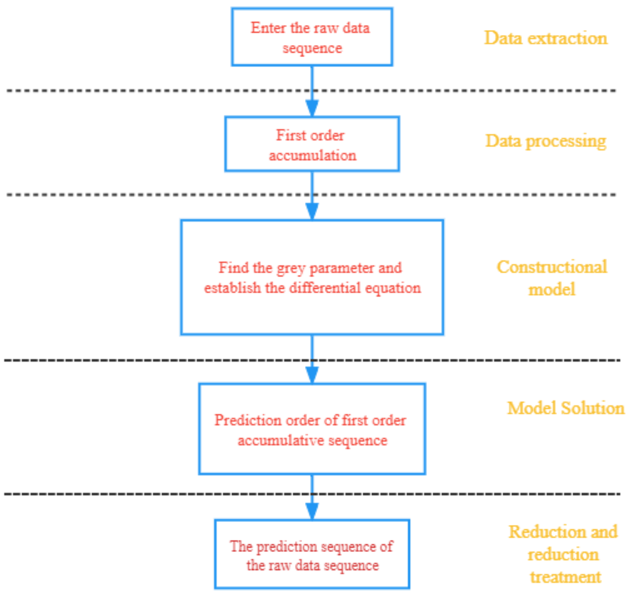

Figure 3: Modeling flow chart of traditional grey prediction model

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After establishing the original nonnegative data sequence $X^{(0)}$

$$X^{(0)} = [x^{(0)}(1), x^{(0)}(2), \cdots, x^{(0)}(j), \cdots, x^{(0)}(n)] \tag{1}$$

Where $x^{(0)}(j) \geq 0, j = 1,2,\cdots,n.$

After the distribution characteristic test of the original data set X (0), use one-time accumulation[11] to generate the accumulated data (accumulation can enhance the regularity of the original data), and obtain a new data sequence. For example

$$X^{(1)} = [x^{(1)}(1), x^{(1)}(2), \cdots, x^{(1)}(\mathrm{k}), \cdots, x^{(1)}(n)] \tag{2}$$

Where $x^{(1)}(\mathrm{k}) = \sum_{j}^{k} x^{(0)}(j), k = 1,2,\cdots,n.$

Quasi smooth sequence, test whether data is suitable for GM (1,1), and analyze the smoothness of the original data by smoothness ratio[12]. Smoothness ratio: the more stable the data changes, The smaller P_k

$$\rho_k = x^{(0)}(k) / x^{(1)}(k-1), k = 2,3,\cdots,n. \tag{3}$$

If the data sequence meets the following two conditions, it can be determined as a quasi smooth sequence, which can be used in GM (1,1) prediction model.

$$\frac{\rho_{k+1}}{\rho_k} < 1, k = 2,3,\cdots,n-1. \tag{4}$$

$$\rho_k \in [0,\delta], \delta < 0.5, k = 2,3,\cdots,n. \tag{5}$$

Establish the grey differential equation[12] of $X^{(1)}$

$$x^{(0)}(k) + a \cdot Z(k) = u, k = 2,3,\cdots,n. \tag{6}$$

Where $Z(k) = 0.5[x^{(1)}(k-1) + x^{(1)}(k)], k = 2,3,\cdots,n.$ In which a and u are the development grey number and endogenous control grey number respectively, which can be fitted by the least square method.

Using the least squares to solve the development grey number a and the endogenous control parameter u of equation (6), let $\alpha = [a,u]^T$, be obtained by using the least squares

$$\alpha = (A^T A)^{-1} A^T B \tag{7}$$

where the accumulation matrix A and constant vector B are as follows:

$$A = \begin{Bmatrix} -0.5[x^{(1)}(1) + x^{(1)}(2)] & 1 \\ -0.5[x^{(1)}(2) + x^{(1)}(3)] & 1 \\ -0.5[x^{(1)}(3) + x^{(1)}(4)] & 1 \\ \cdots & \cdots \\ -0.5[x^{(1)}(n-1) + x^{(1)}(n)] & 1 \end{Bmatrix} \text{ and } B = \begin{Bmatrix} x^{(0)}(2) \\ x^{(0)}(3) \\ x^{(0)}(4) \\ \cdots \\ x^{(0)}(n) \end{Bmatrix}.$$

Represents the new data sequence $X^{(1)}$ as a first-order differential equation[12] in the following form:

$$\frac{dx^{(1)}(t)}{dt} + ax^{(1)}(t) = u \tag{8}$$

solving the differential equation:

$$x^{(1)}(t) = u/a + [x^{(0)}(1) - u/a]e^{-ak} \tag{9}$$

generating the response formula of the prediction sequence $X^{(1)}$:

$$x^{(1)}(k+1) = u/a + [x^{(0)}(1) - u/a]e^{-ak}, k = 1,2,\cdots,n. \tag{10}$$

$$x^{(1)}(1) = x^{(0)}(1). \tag{11}$$

performing progressive reduction[11] to obtain the arithmetic expression of the predicted value of the original data sequence $X^{(0)}$:

$$x^{(0)}(k+1)=x^{(1)}(k+1)-x^{(1)}(k)=u/a+(1-e^{a})[x^{(0)}(1)-u/a]e^{-ak},k=1,2,\cdots,n. \tag{12}$$

$$x^{(0)}(1)=x^{(0)}(1) \tag{13}$$

The accuracy of the test model depends on the mean square deviation ratio c and the small error probability p. The posterior error ratio c indicates the error between the predicted value and the actual value. The smaller the value, the smaller the error. Small error probability p refers to the probability that the absolute value of the difference between the residual and the mean value of the residual is less than 0.6745 times the mean square deviation of the original data. If its value is large, it indicates high accuracy. The calculation method[11] is as follows:

$$c=\sqrt{\frac{\sum_{k=1}^{n}[e(k)-P_e]^2}{\sum_{k=1}^{n}(x^{(0)}(k)-\bar{x}^{(0)})^2}}, \tag{14}$$

$$p=p\{|e(k)-P_e|<0.6745\sqrt{\sum_{k=1}^{n}[x^{(0)}(k)-\bar{x}^{(0)}]^2/(n-1)}\}. \tag{15}$$

Where $\bar{x}^{(0)}=\frac{1}{n}\sum_{k=1}^{n}x^{(0)}(k)$, $e(k)=x^{(0)}(k)-\hat{x}^{(0)}(k)$, $P_e=\frac{1}{n}\sum_{k=1}^{n}e(k)$.

When the mean square deviation ratio C increases, the small error probability will be reduced and the accuracy of the prediction model will be reduced. When the inspection meets the standard, GM (1,1) model can be used for prediction. See Table 2 for the in store standard of GM (1,1) grey prediction accuracy inspection[12,13].

Table 2: GM (1,1) model prediction accuracy registration form

Inspection index	Excellent level	Qualification level	Reluctantly	Unqualified level
c	[0,0.35)	[0.35,0.50)	[0.50,0.65)	[0.65,+∞)
p	(0.95,1]	(0.8,0.95]	(0.7,0.8]	(0,0.7]

4.2. Allocation model

Because the carbon emission right allocation indicators in the middle and lower reaches of the Yellow River include not only quantitative indicators, but also qualitative indicators. At the same time, the impact of each indicator on carbon emission right allocation is different. Therefore, the combination of critc method and fuzzy optimization method[14,15] is adopted to allocate carbon emission rights scientifically and reasonably .

4.2.1. Determine the weight

The contribution of each indicator to the allocation of carbon emission rights is different, so its weight is also different. At the same time, some qualitative indicators under the principles of efficiency and sustainability are more complex; The standard is fuzzy[14], which increases the difficulty of determining the weight. Critical method can effectively solve the above problems. Critical method[15] is a new objective weighting method proposed by diakoulaki in 1995. It mainly comprehensively considers the contrast intensity and conflict between the characteristic values of indicators. The contrast intensity refers to the impact of the same indicator value on different schemes, which is usually expressed in standard deviation. The larger the standard deviation, the greater the gap between schemes, and the greater the amount of information reflected by the data. The conflict of each indicator refers to the correlation between the two indicators. If there is a strong positive correlation, the smaller the conflict, the

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greater the amount of information reflected by the data. The specific calculation is as follows [16].

Amount of information contained in the ith index F:

$$F_i = S_i \sum_{j=1}^{m} (1 - X_{ji}) \tag{16}$$

Where: S_i is the standard deviation of the ith index; X_{ji} is the correlation coefficient between index j and i; $\sum_{j=1}^{m}(1-X_{ji})$ is the quantitative indicator of the conflict between the ith indicator and other indicators. The larger the F_i, the greater the amount of information contained in the ith index, and the index is relatively more important.

(1) Calculate the objective weight of the ith index q:

$$q_i = \frac{F_i}{\sum_{i=1}^{n} F_i} \tag{17}$$

4.2.2. Determining the preferential degree of indicators

In the regional distribution of carbon emission rights, policy and technical factors have a strong impact on it. Such factors are qualitative indicators, difficult to quantify, and are also affected by experience and knowledge. Using the fuzzy optimization method to normalize the regional allocation index value of carbon emission rights, and adopting the unified standard optimization scheme can not only effectively solve the multi decision-making problem, but also reduce the impact of empirical knowledge.

Establish the index eigenvalue matrix[17]. The regional allocation of carbon emission rights is carried out in Inner Mongolia, Shaanxi Province, Shanxi Province, Henan Province, Hebei Province and Shandong Province in the middle and lower reaches of the Yellow River. Each province is composed of N indicators. Therefore, the eigenvalue matrix of the index system is:

$$G_{(m\times n)} = \begin{bmatrix} k_{11} & k_{12} & \cdots & k_{1n} \\ k_{21} & k_{22} & \cdots & k_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ k_{m1} & k_{m2} & \cdots & k_{mn} \end{bmatrix}$$

Calculate the relative superior membership of the index[17]. When obtaining the characteristic values of indicators, due to the problems of the nature of indicators and the calculation unit of indicators, there is a large difference in the characteristic values of indicators, which will lead to the drowning of some influencing factors with small values but great impact on the allocation of carbon emission rights. Therefore, it is necessary to carry out dimensionless quantitative treatment on the characteristic values of indicators to eliminate the impact of different characteristic values of different indicators, That is to say, the bigger the better type and the smaller the better type are calculated as follows:

The larger the better type index relative superior membership degree:

$$M_{ij} = \frac{C_{ij}}{\max_{j=1,\cdots,n}\{C_{ij}\} + \min_{j=1,\cdots,n}\{C_{ij}\}} \tag{18}$$

The smaller the better type index relative superior membership degree:

$$M_{ij} = 1 - \frac{C_{ij}}{\max_{j=1,\cdots,n}\{C_{ij}\} + \min_{j=1,\cdots,n}\{C_{ij}\}} \tag{19}$$

find the optimal set and the worst set. The optimal set V+ and the worst set V- are defined respectively. The solution in multi-objective optimization is unique, and the index optimal solution is obtained.

$$V^{+}=\{Q_1,Q_2\} \tag{20}$$

Where $Q_1=\max_{j=1,\cdots,n}\{C_{ij}\}$ is the optimal solution of the index of larger and better type; $Q_2=\max_{j=1,\cdots,n}\{C_{ij}\}$ is the optimal solution of the smaller and better type index.

$$V^{-}=\{Q_1,Q_2\} \tag{21}$$

Where $Q_1=\max_{j=1,\cdots,n}\{C_{ij}\}$ is the worst solution of the smaller and better index; $Q_2=\max_{j=1,\cdots,n}\{C_{ij}\}$ is the worst solution of the index of the larger and better type.

4.2.3. Determine the regional distribution proportion of carbon emission rights

Use the weight qj of each index, the best set V+ and the worst set V-, and calculate the relative superiority degree of different regions[17] according to equation (22).

$$W_j=\left|1+\frac{\sum_{i=1}^{m}[q_i(V_i^{+}-C_{ji})]^2}{\sum_{i=1}^{m}[q_i(V_i^{-}-C_{ji})]^2}\right|^{-1} \tag{22}$$

normalize the relative degrees of each region:

$$P_j=\frac{W_j}{\sum_{j}^{n}W_j} \tag{23}$$

5. Empirical analysis

5.1. Data processing and distribution results

According to the Yearbook of the National Bureau of statistics, the Yearbook of China's energy statistics and the statistical yearbook[18] of various regions in the middle and lower reaches of the Yellow River from 2011 to 2019, quantitatively adopt the trend of time series and use the grey prediction model to predict the index value in 2025, as shown in Table 3.

Table 3: Forecast of carbon emission in the middle and lower reaches of the Yellow River in 2025

Index	Inner Mongolia	Shaanxi	Shanxi	Henan	Hebei	Shandong
population size (Ten thousand people)	2372.82	4092.45	3448.63	10344.77	7900.04	10772.09
population growth rate (%)	1.76	5.30	5.55	7.74	4.86	20.39
Regional historical emissions (Million tons)	677.29	1233.08	3078.49	478.26	160.13	1396.05
Proportion of secondary industry	33.94	35.88	24.96	38.96	35.11	33.30

(%)						
Energy consumption (Million tons)	26109.66	21197.31	19482.55	24222.22	38501.93	59061.03
Per capita GDP (Yuan)	106726.79	94928.02	50482.64	85183.24	56527.74	109447.92
Carbon emission intensity (ton/ten thousand yuan)	0.0208	0.0343	0.2551	0.0058	0.0035	0.0111
Energy consumption of industrial added value (standard coal) (ton/ten thousand yuan)	3.91	2.09	5.50	1.00	2.96	1.92
Energy consumption intensity (ton/ten thousand yuan)	1.01	0.55	1.19	0.29	0.87	0.51
Net outflows of GDP (billion)	22946.83	41195.58	10674.25	79007.38	33185.74	109076.54
forest coverage rate (%)	25.58	46.78	26.49	30.22	35.00	19.25

The value of each index varies, and the index with small value is easy to be submerged by the index with large value. In order to eliminate the influence of dimension, it is necessary to standardize each index. Population, population growth rate, regional historical carbon emissions, proportion of secondary industry, energy consumption, per capita GDP, carbon emission intensity, energy consumption of industrial added value, energy consumption intensity, net outflow of GDP and forest coverage belong to the larger the better indicators; Carbon emission intensity, energy consumption of industrial added value and energy consumption intensity belong to the smaller, the better indicators. The larger the better type index and the smaller the better type index are normalized[17] as shown in equations (24) and (25) respectively

$$Z_{ij} = \frac{x_{ij}}{\max\limits_{1\le i\le n} x_{ij}} \tag{24}$$

$$Z_{ij} = \frac{\min\limits_{1\le i\le n} x_{ij}}{x_{ij}} \tag{25}$$

Where: X_{ij} is the value of j indicators in area i; Z_{ij} is the value after normalization. The weight of each index is calculated according to equations (16) and (17), and the optimal set V^+ and the worst set V^- are defined. The solution in multi-objective optimization is unique. The optimal solution and the worst solution are obtained according to equations (20) and (21), as shown in table 4.

Table 4: weight of each index, optimal solution and worst solution

Index	Objective weight	Optimal solution	Worst solution
population size	0.1030	0.9582	0.2085

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population growth rate	0.0862	0.9582	0.0815
Regional historical emissions	0.1065	0.9109	0.0569
Proportion of secondary industry	0.0435	0.9852	0.5836
Energy consumption	0.0723	0.9582	0.3005
Per capita GDP	0.0729	0.9582	0.4201
Carbon emission intensity	0.1313	0.0891	0.9852
Energy consumption of industrial added value (standard coal)	0.1045	0.0891	0.8231
Energy consumption intensity	0.1042	0.0891	0.7643
Net outflows of GDP	0.0985	0.9582	0.0891
forest coverage rate	0.0773	0.8815	0.3942

Using each index weight q_j, the best set V^+ and the worst set V^-, calculate the relative superior membership degree of different regions according to equation (22) and normalize it. The results are shown in Table 5. The visualization results are shown in Figure 4.

Table 5: istribution proportion of carbon emission rights in the middle and lower reaches of the Yellow River in 2005

Index	W_i	Normalization
Inner Mongolia	0.2859	0.0951
Shaanxi	0.5134	0.1708
Shanxi	0.1821	0.0606
Henan	0.7170	0.2386
Hebei	0.4256	0.1416
Shandong	0.8815	0.2933

5.2. Discussion on allocation results

Under different allocation principles, the allocation results of carbon emission rights are different. Some scholars advocate the principle of "fairness" and allocate carbon emission rights in full accordance with the principle of fairness, while some scholars believe that the principle of efficiency is more important and only rely on the principle of carbon emission intensity to allocate carbon emission rights. Through the comparative analysis between Figure, some problems can be found. The distribution scheme under other principles is compared with the scheme in the text, as shown in Table 6. The visualization results are shown in Figure 5, and one, two, three and four represent four schemes respectively.

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Comparing the allocation of carbon emission rights under different principles, the initial quota of regional carbon emission rights is quite different. Under the principle of population size, the distribution proportion of Inner Mongolia, Shaanxi Province and Shandong Province is 0.130, 0.124 and 0.245 respectively, which is basically reasonable. However, Henan Province has more carbon emission allocation quota, more developed agriculture, weaker economic foundation and relatively less CO2 emission. Therefore, the distribution proportion of Henan Province is inconsistent with the actual situation; Under the principle of per capita GDP, there is a great difference between the allocation of different provinces and that under the principle of multiple factors, especially in Inner Mongolia and Shaanxi provinces, while the allocation of Shandong Province with the largest energy consumption is the least; Under the principle of energy consumption of industrial added value, there is a great difference between the allocation of different provinces and that under the principle of multiple factors, especially in Inner Mongolia and Shaanxi Province, Inner Mongolia has the most allocation, while Shandong Province, which has the most energy consumption, has the least allocation. Therefore, when designing the regional distribution scheme of carbon emission rights, we should not only consider the internal characteristics of the region, but also consider the future carbon emission demand of the economic and social development of each province and region. Only in this way, the distribution and actual demand of carbon emission rights among regions will be gradually reduced and more realistic.

Table 6: Comparison of regional distribution proportion of carbon emission rights under different schemes

Index	population size	per capital GDP	Energy consumption of industrial added value	Methods in this paper
Inner Mongolia	0.130	0.208	0.244	0.0951
Shaanxi	0.124	0.208	0.145	0.1708
Shanxi	0.003	0.008	0.131	0.0606
Henan	0.258	0.201	0.151	0.2386
Hebei	0.241	0.172	0.206	0.1416
Shandong	0.245	0.202	0.124	0.2933

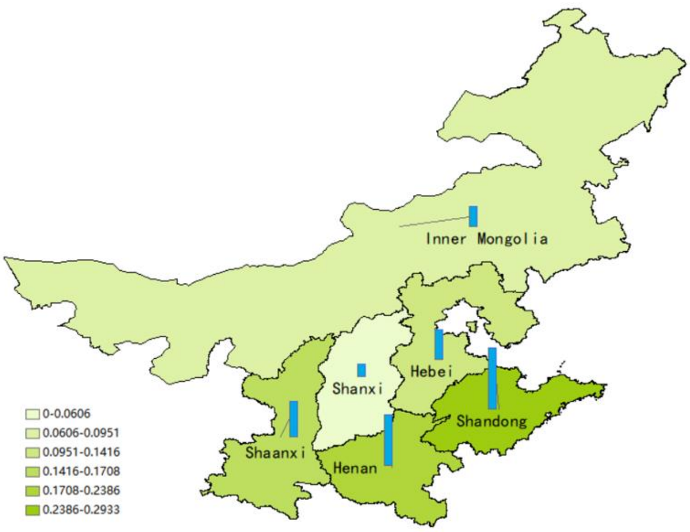

Figure 4: Distribution by region

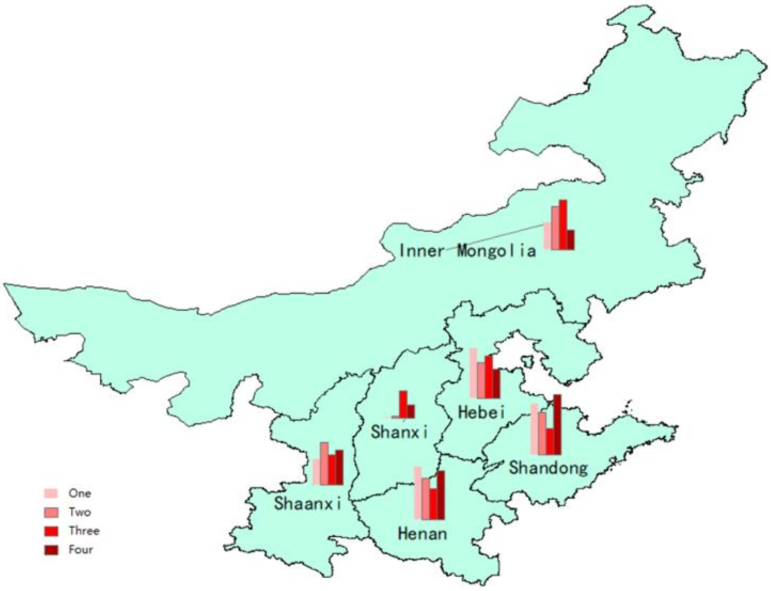

Figure 5: Distribution by region under different programmes

6. Conclusion

The allocation of carbon emission rights needs to consider the principles of fairness, efficiency and sustainable development. Based on the analysis of carbon emission in the middle and lower reaches of the Yellow River, the corresponding index system and distribution model are constructed, and the regional distribution scheme of carbon emission right in the middle and lower reaches of the Yellow River in 2025 is discussed. The comparison shows that the scheme is more in line with the actual situation and more scientific than the single factor allocation, which provides some references for the initial allocation of carbon emissions in China.

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