

Study on the initial allocation of carbon emission permits in the provinces of China based on Shapley method

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Abstract. In China, the initial allocation of carbon emission permits in different provinces is an important issue. It is not only related to whether China can achieve the carbon emission reduction targets, but also the establishment of a national total control and carbon emissions trading market. The cooperation between different provinces and cities can also be more effective in reducing carbon emissions in China. Therefore a plan should be put forward about how to allocate the quota of carbon emissions in China for supporting and promoting cooperation between provinces. For such a purpose, this article use the Gravity model and Shapley value method to estimate the distribution of 2020 carbon emissions quota reallocation in eight different areas of China. The results show that: for different areas, the economic factors, population effects, geographical positions and collaborative carbon reductions should be considered fairly and reasonably to reallocate carbon emission quotas. The results of this paper can provide important information and method for decision makers to establish fair and reasonable carbon-permit market in China.

Introduction

Global warming is one of the most serious environmental problems in the world today. Along with the climate changing and the temperature rising, a lot of countries are aware of the damage caused by the carbon dioxide and other greenhouse gas emissions. Therefore, many countries have been making efforts to reduce greenhouse gas emissions by a variety of ways. In the developing countries like China, with rapid economic growth, the emissions of carbon dioxide are increasing year by year. Many developed countries restrict China's economic growth and take China more obligations to reduce carbon emissions. Under current background, the government must combine with its own economy, resources and environment to establish reasonable carbon dioxide emission reduction policy. Only in this way can China in guarantee the stable economic growth and sustainable development of our country under the premise of response to international pressure. In the process of the implementation of the carbon dioxide emission reduction measures in China, there exists a problem: In different regions of China, how much is the emission reductions in a wide range of industries and how to allocate the existing carbon emissions and carbon emission reduction targets reasonably, fairly and efficiently.

Many researchers have been studied the problem of carbon emissions initial allocation. This paper is mainly about the methods of carbon emissions initial allocation. In China, the initial allocation of carbon emissions is mostly free distribution, and auction allocation only be carried out in pilot cities gradually. Chen et al. put forward two kinds of mixed carbon allocation mechanism

for fairness and efficiency. Both the population and GDP factors weighted allocation method and the GDP penalty factor method based on the population have strengths and weaknesses. Different reduction rate and each country's carbon trading costs under the four kinds of carbon credit allocation mechanism was compared. And they held that the optimal choice is the population and GDP punishment factor weighted hybrid distribution method. Chen also suggested that the carbon trading can relieve the impact of economic production to achieve emission reduction targets[1]. Marco and others studied the quantitative distribution of carbon emission rights from the cultural perspective. They also considered the carbon emissions, energy use, population, technology and economic growth factor. And their research about the perspective of regional carbon emission rights allocation has a lot of impact in the future[2]. Duan et al. proposed that the distribution of the central government to the enterprise quota allocation can make the central government's power too concentrated. The aggregation method and decomposition method, and present regional adjustment coefficient to adjust the quota allocation amount were suggested[3].

This paper takes into account the domestic regional combination of difference between different regions and carbon flow, and studied on the initial distribution of carbon emissions in the province of China based on Shapley method.

Principles and Methods

This article calculates eight kinds of consumption of energy, including coal, coke, crude oil, fuel oil, gasoline, kerosene, diesel and natural gas. Considering the carbon oxidation rate, we can use the method from the IPCC[4] and Liu Zhu[5] to calculate different kinds of energy carbon emission coefficient as Eq. (1), and according to the coefficient of carbon dioxide emissions and China energy statistical yearbook, the carbon dioxide emissions of the thirty provinces and cities of China can be calculated by Eq. (2).

$$COE_i = CV_i \times CVC_i \times COR_i \quad (1)$$

$$C^j = E_i^j \times COE_i \quad (2)$$

Where COE means the coefficient of carbon dioxide emissions, i means the different varieties of energy, CV means the average low calorific value, CVC means the average low calorific value, and COR means carbon oxidation rate, C means the carbon dioxide emissions, E means the energy consumption, j means the different varieties of provinces and cities.

Because of our country rapid economic growth in recent years, the carbon emissions quota is overvalued according to the intensity of carbon emission reduction target of 40%-45%. Therefore, according to the requirement of the national twelfth five-year plan we assume the China's 2005-2020 GDP growth for 8% and the intensity of carbon emission reduction target for 40%. With reference to the classification of energy consumption data of 30 provinces and cities of the Chinese energy statistics yearbook 2006, it can be calculated that the carbon dioxide from the burning of

fossil fuel emissions in 2005 is 7.389 billion tons, and the carbon dioxide emissions target in 2020 should be 14.063 billion tons.

With reference to the calculation method of Du[6], it is easy to get the distributed result of cities and provinces of carbon emissions quota by historical cumulative method as shown in figure 1. Because of Chongqing historical data is not complete and it's a part of Sichuan province before 1997, Chongqing can be merged in Sichuan province.

Table 1. Different kinds of energy coefficient of carbon dioxide emissions.

Energy	<i>CV</i>	<i>CVC</i>	<i>COR</i>	<i>COE</i>
Coal	20908	26.37	0.94	1.9003
Coke	28435	29.5	0.93	2.8604
Crude oil	41816	20.1	0.98	3.0202
Fuel oil	41816	21.1	0.98	3.1705
Gasoline	43070	18.9	0.98	2.9251
Kerosene	43070	19.5	0.98	3.0179
Diesel	42652	20.2	0.98	3.0959
Natural gas	38931	15.3	0.99	2.1622

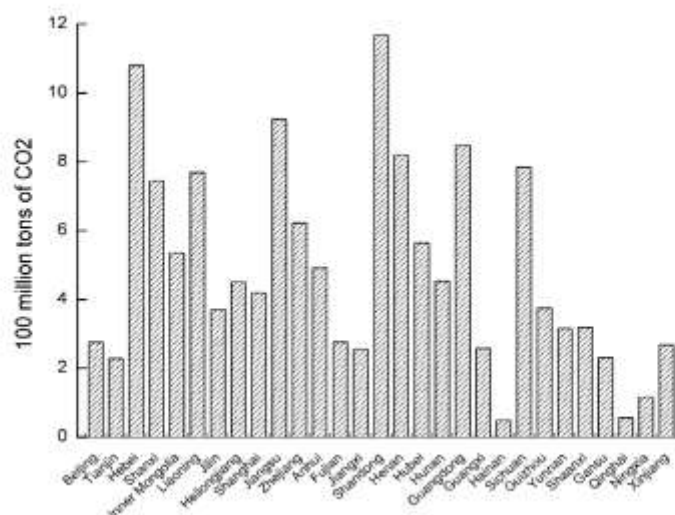


Fig. 1. The provincial history assignment carbon quotas in 2020

According to the geography relations, carbon emissions and GDP data, the twenty-nine provinces and autonomous regions can be divide into eight areas by the methods of He[7] and Zhang[8] as shown in Table 2. They are Northeast, Beijing-Tianjin, Northern coast, Eastern coast, Southern coast, Central region, Northwest, Southwest. It is important to notice that the study don't include Hong Kong, Macao, Taiwan and other regions due to the lack of historical information and parts of date not available. In this paper, the eight regional carbon emissions permits will be allocated and compared.

Principles and Methods

According to economic theory, regional economy between the internal and external different parts

of the joint can more effectively control the carbon emissions. In this paper, we take the gravity model to calculate and evaluate the connection value about the regional economy and emissions reduction. And it can reflect the regional mutual absorption effect and radiation effect. For the different regions of a and b , we calculate the value of regional correlation coefficient R_{ab} according to Eq. (3).

$$R_{ab} = (\sqrt{P_a C_a} \sqrt{P_b C_b}) / D_{ab}^2 \quad (3)$$

where P_a and P_b are the population size of region a and b in 2020 respectively, C_a and C_b are the basic carbon quotas of region a and b in 2020, D_{ab} is the distance between region a and b . And the value of R_{ab} are shown in the following Table 3.

Table 2. China's eight regional division

No.	Region	Provinces
1	Northeast	Heilongjiang, Jilin, Liaoning
2	Beijing-Tianjin	Beijing, Tianjin
3	Northern coast	Hebei, Shandong
4	Eastern coast	Jiangsu, Shanghai, Zhejiang
5	Southern coast	Fujian, Guangdong, Hainan
6	Central region	Shanxi, Henan, Anhui, Hubei, Hunan, Jiangxi
7	Northwest	Inner Mongolia, Shanxi, Ningxia, Gansu, Qinghai, Xinjiang
8	Southwest	Sichuan, Guangxi, Yunnan, Guizhou

Table 3. The value of regional correlation coefficient (ton million ten thousand people/km²)

R	Northeast	Beijing-Tianjin	Northern coast	Eastern coast	Southern coast	Central region	Northwest	Southwest
Northeast	0	9.08	21.51	12.22	3.52	21.92	6.16	4.69
Beijing-Tianjin	9.08	0	82.82	10.09	2.36	27.75	5.96	3.58
Northern coast	21.51	82.82	0	55.67	15.52	277.83	49.50	27.45
Eastern coast	12.22	10.09	55.67	0	28.57	280.95	11.26	20.49
Southern coast	3.52	2.36	15.52	28.57	0	71.62	7.09	43.60
Central region	21.92	27.75	277.83	280.95	71.62	0	47.67	88.55
Northwest	6.16	5.96	49.50	11.26	7.09	47.67	0	22.45
Southwest	4.69	3.58	27.45	20.49	43.60	88.55	22.45	0

Because the eight areas region distance is more difficult to calculate, so the capital cities in the region is calculated on the basis of the average distance. The regional population of 2020 can be estimated according to the natural population growth rate of the Chinese statistics yearbook 2014. In Filar and Gaertner's theory[9], the regions which have higher GDP, more carbon outflow and bigger carbon emission joint value should be given more carbon emission room. Based on the gravity model, we estimate the regional joint carbon emissions $S(Ax)$ as Eq. (4) and Eq. (5).

$$R_a = \sum_{a \neq b} R_{ab} (a, b = 1, 2, 3, \dots, 8). \quad (4)$$

$$S(A^x) = \sum_{a \in A^x} GDP_a \sum_{a \in A^x} Q_a \sum_{a, b \in A^x} \left(\frac{R_{ab}}{R_a} \times 100\% \right) \quad (5)$$

where R_a is the total external carbon reduction connection of region a and reflects the degree of the region's carbon emission reduction connection to others, Q_a is the carbon outflow of region a to other seven regions in 2020. It should be noted that this paper employs the input–output method to calculate the inter-regional carbon outflows, based on the Input–Output Table 2007 of China provinces with eight regions and forty-two sectors and the method of He[10]. In Eq. (5), we set the China's 2014-2020 regional GDP growth hypothesis for 7% for the thirteenth five-year state plan requirement. Then we set $A = [A1, A2, A3, A4, A5, A6, A7, A8]$ representing eight areas, and A^x is a regional combination x in eight areas of subsets. Based on the Shapley value method[11], we can get the carbon dioxide quota allocation proportion coefficient $\Phi(a)$ through the Eq. (6), Eq. (7), Eq. (8).

$$w_a = \frac{(s-1)!(n-s)!}{n!} \quad (6)$$

$$M_a = \sum w_a [S(A^x) - S(A^x / \{a\})] \quad (7)$$

$$\phi(a) = \frac{M_a}{\sum_a M_a} \quad (8)$$

where w_a is the weighting factor, n is the number of regions, and $n=8$ in Eq. (6), s is the number of area in regional subset A . M_a is the Shapley value of region a . It is important to note that this article assumes that the departments of provinces and cities have the same carbon intensity growth ratio, so the carbon intensity of benchmark year does not affect the results in Eq. (5).

Results and Discussion

Based on the Grandfather method and the Shapley value method, we can obtain the results of eight areas of our country carbon quota allocation as shown in Table 4. As for the Shapley value method, all of internal economic, regional carbon outflow and regional position are taken into account. The allocation results are different from the Grandfather method. From the global perspective, Northern coast, Eastern coast, Southern coast and Central region get 64.33% of the total carbon emissions, and it is more than the 35.67% of Northeast, Beijing-Tianjin, Northwest and Southwest significantly. Because of geography factors and negative population growth, the distribution of the Northeast region is only 8.56%, and it decreases by 2.74% compared with the result of the Grandfather method. Because of geography factors and negative population growth. But Beijing-Tianjin get 7.17% for its fast growing economy, and it increased by 4.39%. Due to Eastern coast and Southern coast have bigger carbon outflow, they share more carbon emission room as 16.26% and 12.82%. In addition, it is important to enhance regional cooperation to achieve mutual targets by considering the advantage of geographical position and radiation effect. For this reason, Central region and Northern coast should give more carbon emission rights.

Table 4 Allocation results by the Grandfather method and Shapley method

Name	North east	Beijing-Tianji n	Northern coast	Eastern coast	Southern coast	Central region	North west	South west
Carbon outflow (%)	8.67	7.17	14.21	23.77	18.91	13.19	8.02	6.06
GDP (%)	8.65	5.38	13.19	18.81	13.84	20.23	8.29	11.61
Grandfather method(%)	11.31	3.59	15.98	13.97	8.35	23.67	10.84	12.31
Shapley value method(%)	8.56	7.98	15.63	16.26	12.82	19.62	8.99	10.15

In the thirteenth five-year plan, the government of China also puts the carbon dioxide emissions as the binding forces indicators. To achieve amount and strength of the double control is not only embodying the sense of responsibility and mission as a developing country, but also a new beginning of carbon emissions control. In this paper, the total emissions control and historical cumulative emissions are taken into account, and the results show that the joint difference between different areas in our country. In the future, it is needed to consider more factors about the distribution, including fairness, historical responsibility and economic factors, and so on. Moreover, it is also a long way to build the complete and perfect the system of distribution of carbon quotas.

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