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THE GAME OF INTERESTS IN CHINA'S UNIFIED CARBON MARKET: A PERSPECTIVE OF SUSTAINABILITY

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Abstract

China is currently promoting the construction of a nationwide unified carbon trading market. Theoretically, a unified carbon trading market can play a role in improving the efficiency of carbon trading. However, in the process of transformation from decentralized and pilot carbon trading platforms to a unified national one, the individual differentiation of market participant's increases and risks are different. It is the core issue to ensure more sustainable and healthier development for the unified carbon market to make fair and reasonable income distribution for market participants with differences.The paper uses the Shapley value method to allocate the cooperative benefits in the carbon trade market and then introduces the diversified risk factors borne by participants in the carbon trade market to revise the results of income distributing. The results show that the allocation mechanism considering multiple risk factors is more fair and reasonable. The research results can provide reference for policy making about how to improve the enthusiasm of market participants in the national unified carbon market and promote the sustainable development of the carbon trading market.

Key words: Carbon trading market, income distribution, multiple risk factors

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1. Introduction

Global climate change has caused problems including sea level rise, ecological environment deteriorated and other problems, seriously affecting economic development and the quality of human life. Carbon trading has emerged to deal with the influences of climate change. After the pilot project of carbon trading in many regions, China is now pushing forward the integrated construction of the national carbon trading market. In this process, there are many factors that affect the development process, the core of which is the interest game and profit distribution of carbon trading parties. According to the theory of rational economic man, in the process of carbon trading, there is a profit game among the participants who hope to get the maximum benefit from carbon trading. If the fairness of interest distribution among participants is not solved, their enthusiasm to participate in the unified carbon trading market will be affected and the sustainable development of the unified carbon trading market will be hindered. In fact, the biggest difference between a national carbon market and a pilot carbon market is that market participants may come from different regions and face different risks. Therefore, how to establish a reasonable income distribution mechanism to match the benefits of market participants with the risks they bear is the key to the successful establishment and healthy operation of China's unified carbon market.

Scholars have put forward their own views on solutions to the problem of profit distribution of carbon trade bazaar. Some researchers (Lazarevic Bajec and Maruna, 2015; Wang et al., 2019) studied

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the benefit distribution of regional cooperation in emission reduction under carbon trading policies. Some researchers (Fodor and Bányai, 2014; Lv et al., 2019) found that the carbon tax mechanism can be adjusted to solve the interest game between enterprises and the government. Zhang and Zhao (2011), by studying the distribution for interests among government, enterprises and financial institutions through the tripartite game model, proposed that the government's decision-making on carbon agora would have impacts on the enthusiasms of enterprises to participate, thus producing effects on the development of the carbon transacting bazaar. Xie and Dou (2014) analyzed the carbon emission related benefit distribution mechanism based on the decision rights of participants under the framework of cooperative game model.

Shapley value method is a powerful tool to complete the benefit distribution of alliance members. It be used to study the benefit distribution in the carbon trading market (Tan et al., 2013). Moreover, the Shapley value method with multiple weights can be used to explore the reasons for regional differences in carbon emission intensity in China, and the regional dimension of carbon trade participants' contribution assessment (Wang and Yang, 2016). Also, scholars further discusses the uncertain factors of interest distribution in carbon market (Luo and Liang, 2011) and consider all kinds of factors that affect the fairness and rationality of trade, and improve the efficiency of income distribution (Dinar and Howitt, 1997), and put forward the strategy of the dynamic cooperative alliance income distribution (Petrosjan and Zaccour, 2003).

To sum up, there are few studies on the relationship between risk factors and income distribution mechanism in the nationwide carbon market, and the existing studies are mainly on the secondary market income distribution in a few pilot areas (Diaz-Rainey and Tulloch, 2018). This paper attempts to include all the seven carbon trading pilot projects, and studies the income distribution of carbon trading market by using Shapely value method and adding risk factors.The specific method is to consider the actual risks faced by carbon trading participants in each region, and use the analytic hierarchy process (AHP) to include the risk factors faced by the participants and calculate the weight, combined with the score of experts on the risk factors, the risk coefficient is obtained. Then, the traditional Shapley value method is modified by risk coefficient. By comparing the distribution results before and after amending, and combining with the actual situation of regional development, it can be seen that the income distribution after amending is more in line with the situation of regional technology and economic development, which makes the income distribution more reasonable. This paper is to fully cover all seven carbon trading pilot regions in China, and consider the difference risks among different regions to put forward a more reasonable benefit distribution mechanism of the carbon trading market. The study of the paper can provide a reference for policy making of carbon transacting marketplace.

2. Materials and method

2.1. Distribution of revenue based on traditional Shapley value method

Shapley value method, proposed by Shapley, is to solve benefit allotting in multi-person cooperation. When the benefit activities aren't confrontational, the increase in the number of people in the cooperation will not lead to ta decrease in the benefit. In this way, the cooperation of all n individuals will bring the maximum benefit. Shapley value method is a scheme to distribute the maximum benefit. According to the literature (Xu et al., 2016), this paper sets I= {1, 2, 3, 4,..., n}, and if there is a function v(s) corresponding to any subset s (representing any combination in the set composed of n individuals) in I, it can be got expressed as Eqs. (1-2):

$$v(\varphi) = 0 \tag{1}$$

$$v(S_1 \cup S_2) \geq v(S_1) + v(S_2),\ S_1 \cap S_2 = \emptyset \tag{2}$$

v(s) is defined as the characteristic function, which represents the benefit of cooperative s. Eqs. (1) and (2) embody the idea of "synergy". It means that the profit of cooperation of partners is more than that of non-cooperation (Eq. 2), and cooperation will not damage individual interests, and all partners have the maximum profit when they cooperate (Fankhauser and Hepburn, 2010). The maximum cooperation profit is recorded as v (I).

Based on cooperation I, $\varphi_i(v)$ is used to representing a part of the income that the i^{th} member of I should get from the maximum income v(I), then the distribution of cooperation income is expressed as (Eq. 3):

$$\varphi(v) = (\varphi_1(v),\ \varphi_2(v), \cdots,\ \varphi_n(v)) \tag{3}$$

The successful cooperation must meet the following conditions expressed as Eqs. (4-5):

$$\sum_{i=1}^{n} \varphi_i(v) = v(I) \tag{4}$$

$$\varphi_i(v) \geq v(i), \quad i = 1,2,\cdots,n \tag{5}$$

Under cooperation I, the profit distribution of each partner determined by Shapley value method is expressed as (Eq. 6):

$$\varphi_i(v) = \sum_{S \in I} W(|s|)[v(s) - v(s/i)], i = 1,2,\cdots,n \tag{6}$$

The W(|s|) from (Eq. 6) may be expressed as (Eq. 7):

$$W(|s|) = \frac{[(n - |s|)!\,(|s| - 1)!]}{n!} \tag{7}$$

where: s (i) is all subsets of partner i in the set I; |s| is the number of elements in subset s; n is the number of elements in the set I; W(|s|) is the weighting factor; v(s) is the benefit of subset s; v(s/i) is the cooperative benefit when the participant i is removed from subset s. Based on the above, benefits shared by participants in the carbon trade market can be gained.

2.2. Distribution of return by Shapley value method with risking factors

The above doesn't consider the introduction of risk factors to modify the existing results. However, there are three premises for the Shapley value method (Xie and Dou, 2014). They are equal willingness and the equal force for negotiation for participants' in the carbon trade market, and the 100% possibility for establishing the carbon trade market. However, due to the different risks and participants' negotiation abilities, the Shapley value results may affect participants' cooperation willingness. The paper considers the risk factors to modify the income distribution.

Considering the size of the risks undertaken by all parties involved, two types of risk factors, namely system risk D1 and Non-system risk D2, are integrated into the setting of risk revision factors to enhance the rationality of income distribution by the Shapley value method.

2.2.1. Construction of risk indicator system affecting income distribution

Scholars divide the risk factors affecting participant's enthusiasm into market risk, technology risk and cooperation risk (Luo and Liang, 2011). Other scholars highlight the factors affecting participants, including risk factor, investment factor and effort factor (Wang et al., 2011).The paper divides risk factors into systematic risk and non-systematic risk.System risk D_1 is divided into technical risk D_{11} and competitive risk D_{12}. Technology risk D_{11} is the risk brought by market technology innovation. Competitive risk D_{12} is the risk caused by the combination of competitors or upstream and downstream, and Changes in partner decision-making pose risks to participants. Non-systematic risk D_2 is the internal risk of an enterprise, which can be controlled. It refers to effort risk D_{21}, cooperation risk D_{22} and investment risk D_{23}. Specifically, effort risk D_{21} refers to the risk that participants' efforts will be affected by their interests in the process of building the carbon trade market; cooperation risk D_{22} refers to the risk caused by differences in geographical location and management; the investment risk D_{23} refers to the risk that participants may not get a reasonable return on their investment in the human and financial aspects of the carbon trading market. It is shown in Fig. 1.

2.2.2 Determination of the weight of risk indicators

This paper uses AHP to calculate the weight of each risk factor (Wang et al., 2011). Firstly, this paper designs the relevant questionnaire for risk factors and send it to experts and invite experts to reply to it. Secondly, according to the results of the questionnaire, the index weight is calculated by the software.

2.2.3 Determination of risk coefficient

The accuracy of the data is difficult to determine. Therefore, this paper firstly issues a questionnaire and invites experts to rate the probability of relevant risks and the probability of losses caused by risks. Secondly, the risk coefficients of participants are calculated.

If risk R dominates n elements $R_1, R_2, \ldots, R_n$, and the weight of each element relative to R and their risk coefficients are as follows: $W_1, W_2, \ldots, W_n$ and $D_1, D_2, \ldots, D_n$, and the risk coefficients at all levels can be obtained, according to $R = \sum D_i \times W_i, i = 1,2,\cdots,n$ (Sun, 2009). Finally, according to $R = P_f + C_f - P_f \times C_f$ (Dai and Xue, 2004; Nishide and Yuan, 2011; Sun, 2009), the risk coefficients of risk factors can be calculated. P_f is the probability of risk occurrence and C_f is the probability of loss caused by risk occurrence. At the same time, this paper will deal with the risk coefficient dimensionless to avoid the influence of different dimensions on the income distribution, that is, divide the risk coefficient by the sum of the risk coefficients, and then get the normalised risk coefficient to modify the income distribution of the market.

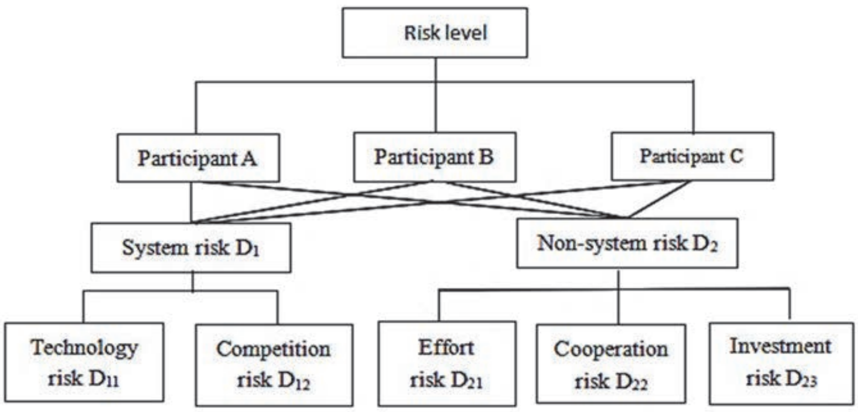

Fig. 1. Risk Factor Index System

2.2.4 Revised Shapley value method for income distribution

According to $\varphi_i'(v) = R_i \times \varphi_i(v)\ (i = 1,2,3)$ and the risk coefficients obtained above, the allocation results can be modified. By comparing the distribution results before and after modifying, participants who take more risks will get more benefits; on the contrary, participants who take fewer risks will get less income.

3. Case studies

In the following, we will take seven pilot areas of China's carbon trading market as the research object to study participants' interest distribution. First of all, the traditional Shapley value method is used to calculate participants' income in the carbon trading market; secondly, the risk factors of participants are included to modify the income distribution results of the traditional Shapley value method; finally, the usefulness of the modified Shapley value method is obtained by comparing the situation before and after the modification of the income distribution results of the Shapley value method.

The case of this paper includes carbon trading pilot markets in all seven regions of China, which is different from previous literature that only select 3 or 4 carbon trading pilot markets. The data in this paper are from China's carbon emission trading network from 2013 to 2019, and the data are reliable.

3.1. Revenue distribution by traditional Shapley value method

The best research object of income allocation in carbon market should be the national carbon trading market. However, at present, only the power industry is included in the national carbon trading market, and other industries are not yet involved. The research on the interest distribution of the market involves a relatively narrow range of industries, which makes the research on it not universal (Hood, 2010; Kallbekken, 2005; Kerr et al., 2013; Wettestad, 2005). The scope of the industry involved is relatively narrow and the study of income distribution is not universal. In addition, the time to establish a unified carbon trading platform is relatively short, and the data reference is not very good.

In contrast, the carbon market in the pilot areas has a wide range of industries, a relatively long time to establish the market, and rich experience and data. Therefore, the cumulative carbon trading volume of seven Chinese carbon trading pilot markets is selected as the case data. The time period is from 2013 (the year China's carbon trading pilot was launched) to the end of 2019.

This paper uses the total carbon trading volume of seven pilot carbon trading markets by the end of 2019 (Table 1) to determine participants' cooperative earnings in the carbon trading market. According to it, seven pilot projects are merged into three groups. Tianjin, Chongqing, Beijing and Shenzhen carbon trading markets with low carbon trading volume (less than 15%) are set as Group A. Hubei market with high carbon trading volume (more than 30%) is set as Group C. Group B includes Shanghai and Guangdong carbon trade markets (all between 15% and 30%). And the paper will get an alliance $I = \{A, B, C\}$. Similarly, if A, B and C participate in the unified carbon trade market independently, the returns can be respectively 21, 39 and 40. Therefore, the paper assumes that AB, AC and BC two alliances can, respectively, obtain income: 65, 66 and 84, and that of alliance ABC is 110, assuming that other ways cannot obtain profits. It can be seen that when carbon trade is conducted in the unified carbon trading market independently, the profits of cooperation are more than that of non-cooperation, and when all partners participate in the market, the profits are the largest. On account of the above assumptions, the income scale of each alliance can be got (Table 2). From data in Table 2, it can be got that the interest of A ($\varphi_1(v)$) by Shapley value method is 24.3333 (Table 3). Similarly, benefits of B ($\varphi_2(v)$) and that of C ($\varphi_3(v)$) are 42.3333 and 43.3333 respectively. Therefore, the distribution obtained in the national carbon trade market is more than that of parti cipants' independent carbon trading. By participating in the unified carbon trading market, participants can improve the rationality of income distribution.

3.2. Income distribution by revised Shapley value method

The mentioned income distribution method above lacks consideration of the risk factors undertaken by participants in the carbon trading market. But the risk factors for carbon trading market participant's decisions have a significant impact, so the articles in this section will discuss how to consider the participants of the actual risk factor to correct the traditional Shapley value method to get a more reasonable income distribution results.

3.2.1 Determination of Index Weight

Based on the index system of risk factors and AHP method, weights of system risk D_1 and non-system risk D_2 are 0.8571 and 0.1429, respectively.

Table 1. Share of accumulated carbon trade in seven

Regional distribution	*Shanghai*	*Beijing*	*Guangdong*	*Shenzhen*	*Tianjin*	*Hubei*	*Chongqing*
Cumulative carbon trading volume (%)	23	7	16	10	1	40	3

Note：Data is from China Carbon Emission Trading Network (www.tanpaifang.com)

Table 2. Income from alliances

Alliances	*A*	*B*	*C*	*AB*	*AC*	*BC*	*ABC*
Earnings v(s)	21	39	40	65	66	84	110

Table 3. Shapley values (A's income distribution)

	A	*AB*	*AC*	*ABC*
v(s)	21	65	66	110
v(s/A)	0	39	40	84
v(s)-v(s/A)	21	26	26	26
|s|	1	2	2	3
W(|s|)	1/3	1/6	1/6	1/3
W(|s|)[v(s)-v(s/A)]	21/3	13/3	13/3	26/3
$\varphi_1(v)$	24.3333			

Specifically, weights of technology risk D_{11} and competition risk D_{12} are 0.7347 and 0.1224, respectively, and that of effort risk D_{21}, cooperation risk D_{22} and investment risk D_{23} are 0.0327, 0.0108 and 0.0994 respectively. It is shown in Table 4.

3.2.2 Risk coefficient calculation

Because the risk coefficient calculating equation is $R = P_f + C_f - P_f \times C_f$. P_f is the probability of risk occurrence, and C_f is the probability of loss caused by risk occurrence ($P_f < [0,1]$, $C_f < [0,1]$) (Dai and Xue, 2004; Nishide and Yuan, 2011; Sun, 2009).

Experts are invited to score the probability of risk occurrence and loss caused by risk occurrence, so that the data obtained are relatively reasonable, as shown in Table 5. Based upon Table 5, the risk coefficients of A, B and C are: R_1=0.6935; R_2=0.7265; R_3 = 0.6294. In order to avoid the influence of dimension on the results of revenue distributed, the risk coefficients of A, B and C are normalized as follows: R'_1=0.3384; R'_2=0.3545; R'_3=0.3071.

3.2.3 Income distribution

This paper uses $\varphi'_i(v)$ (i = 1,2,3) to express the modified result of the income distribution of Shapley value method. Then, according to the Shapley value before correction, the following results are obtained (Eqs. 8-10):

$$\varphi'_1(v) = \varphi_1(v)[1+(0.3384-0.3333)] = \\ = 24.3333\times[1+(0.3384-0.3333)] = 24.4574 \tag{8}$$

$$\varphi'_2(v) = \varphi_2(v)[1+(0.3545-0.3333)] = \\ = 42.3333\times[1+(0.3545-0.3333)] = 43.2308 \tag{9}$$

$$\varphi'_3(v) = \varphi_3(v)[1+(0.3071-0.3333)] = \\ = 43.3333\times[1+(0.3071-0.3333)] = 42.1980 \tag{10}$$

Table 4. Weights of indicators

	First Level Index	*Two Level Index*
Risk factor	System risk D_1 (0.8571)	Technology risk D_{11} (0.7347)
		Competition risk D_{12} (0.1224)
	Non-systematic risk D_2 (0.1429)	Effort risk D_{21} (0.0327)
		Cooperation risk D_{22} (0.0108)
		Investment risk D_{23} (0.0994)

Table 5. List of risk factors

First Level Index	*Two Level Index*	*Alliance*	*Risk Probability P_f*	*Loss Probability C_f Caused by Risk Occurrence*	*Risk Coefficient*
System risk	Technology risk D_{11}	A	0.70	0.80	0.94
		B	0.80	0.90	0.98
		C	0.50	0.70	0.85
	Competition risk D_{12}	A	0.70	0.50	0.85
		B	0.80	0.60	0.92
		C	0.60	0.40	0.76
Non-systematic risk	Effort risk D_{21}	A	0.70	0.50	0.85
		B	0.80	0.60	0.92
		C	0.50	0.40	0.70
	Cooperation risk D_{22}	A	0.30	0.70	0.79
		B	0.30	0.80	0.86
		C	0.50	0.50	0.75
	Investment risk D_{23}	A	0.30	0.30	0.51
		B	0.30	0.30	0.51
		C	0.50	0.40	0.70

4. Results and discussion

4.1. Risk factors affect the benefit distribution of carbon trading market participants

The data in Table 6 are the comparison before and after the revision of participants' income distribution results in the carbon trading market. It can be seen (Table 6) that, compared with the traditional Shapley value method, after the introduction of risk factors, the returns of each alliance A, B and C have changed, indicating that the risks of each alliance from different regions are different. According to the theory of high risk and high return, the higher the risk, the higher the return. The Shapley value method with risk correction is more reasonable and reliable.

Table 6. Income distribution comparison

	Shapley value	*Revised Shapley value*
Alliance A	24.3333	24.4574
Alliance B	42.3333	43.2308
Alliance C	43.3333	42.1980

4.2. The development degree of regional economy affects the risk coefficient of market participant

After the introduction of risk factors, the income of A and B in the carbon trading market has increased, while that of C in the carbon trading market has decreased; at the same time, the income distribution increase of A is smaller than that of B. This is because the regions where A and B are located belong to the developed regions, and their economies are relatively developed, while the economy of the region where C is located are relatively backward. Meanwhile, compared with B, B is more economically developed than A. The more developed the region, the greater the risk the alliance enterprises take.

In economically developed regions, the greater the possibility of technological innovation is, the greater technical risk D_{11} is. Similarly, the greater competition risk is in developed regions, the greater competition risk D_{12} is. The competition will be higher in developed regions, and if there is a little carelessness, the income of enterprises will be decreased, so efforts risk D_{21} is greater. Cooperation risk D_{22} is the willingness of enterprises to cooperate, and the development of regional economy will have an impact on the ability to acquire resources. Therefore, the interest game of enterprises in developed regions have a larger voice and a smaller cooperation risk. Meanwhile, there are many enterprises that carry out technological innovation in developed regions, so competition is relatively large, and the possibility that the resources invested cannot get the return is large, so investment risk D_{23} is large. Therefore, because the regions of A and B belong to the developed regions, their technology risk, competition risk, effort risk are relatively high. While the economy of the region of C is relatively backward, the technology risk, competition risk, effort risk will naturally be lower. In terms of risk-bearing, B bears the maximum risk (technology risk, competition risk, effort risk), so it is much riskier than A, and the income distribution increase of B is the largest.

5. Conclusions

This paper adopts Shapley value method and introduces risk factors to study the benefit distribution mechanism of carbon trading market. It is found that Shapley value method with risk correction factor is more objective and reasonable for carbon market income distribution, because it can reflect the actual risk factors of different market participants and conform to the principle of matching risk and income.

The conclusion of this paper can provide a reference for policy makers to consider how to improve the enthusiasm of carbon market participants and promote the sustainable development of carbon trading market in the process of carbon market transition from pilot to unify.

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