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Research Article

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Research on the Distribution of Green Supply Chain Income of Thermal Coal based on the Shapley Value Method

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Abstract Under the background that economic globalization and green sustainability are listed as important prerequisites for development, the form of market competition is not only competition among enterprises, but also gradually evolves to competition between supply chains under the influence of various factors, and the links and cooperation between all parties in the supply chain are becoming more and more close. However, the operation of enterprises is for profit purposes, in the face of interests all parties want to maximize their own interests, so it has caused a double marginal effect, and even increase energy consumption. Based on the research topic of green supply chain and income distribution of thermal coal, this paper analyzes the status quo of income distribution of power plants, takes into account the contribution of the environment to the distribution of income, analyzes the feasibility with shapley value modeling, and finally draws the conclusion that the distribution of income considering green contribution is more fair and reasonable.

Keywords Thermal coal green supply chain, revenue distribution, green sustainable, supply chain management

Introduction

From the study on the proportion of thermal coal to coal use in previous years, it can be seen that the proportion of thermal coal in developed countries is the highest, with an average of more than 85%, compared with developing countries, the proportion of thermal coal is also rising steadily year by year. Since the end of the last century, foreign research on the supply chain management of thermal coal has developed rapidly, and this field has become the focus of scholars.

The Concept Of A Green Supply Chain Was First Proposed By The Michigan State University Manufacturing Research Association In 1996. It is also known as the "Environmental Awareness Supply Chain" or "Environmental Supply Chain". As a modern management method that takes into account the comprehensive utilization of environment and resources, its purpose is to ensure the sustainable development of enterprises and society. In view of the steady development of the green supply chain of thermal coal, Kinkeuinglai (2019) and others set up a new evaluation system for green coal suppliers according to the characteristics of the thermal power supply chain itself, and then used the main component analysis (PCA) to establish the main evaluation index, using the support vector machine (SVM) to establish the evaluation model. Peiliua (2017) et al. described the challenges facing the current thermal coal industry from a supply chain perspective and made technical and policy recommendations to address them.

At present, many domestic experts and scholars have also done a lot of research on the distribution of income in the green supply chain of thermal coal. Li Wei (2016) suggested that the distribution of tripartite gains in the supply chain should be linked to the risks taken, considering the risks taken by the parties in a specific supply and demand relationship, political environment and economic environment, and avoiding the multiple marginal effects in the supply chain. Wang Chong (2018) proposes that the supply chain revenue distribution model should fully integrate the responsibilities and contributions of all parties in the supply chain to establish. Liu

Shuo (2014) simplified the green supply chain of thermal coal into a three-tier supply chain and established a revenue distribution contract model, arguing that the implementation of the revenue-sharing contract would increase the order volume of the thermal coal supply chain and increase the expected sales volume and the total profit of the thermal coal supply chain.

1. Green constraint

A good ecological environment is the basis for ensuring the high quality of life of residents, and it is also a prerequisite for the rapid and steady development of social economy. With green constraints, the distribution of income in the supply chain is limited by green constraints, so the green constraints on enterprises and supply chains must be taken into account when establishing the income distribution model.

1.1. Green logistics

From the basic situation of the power plant we can understand that its development philosophy is closely around the word "green". Enterprises also respond to the national green restraint policy from all aspects. Especially in transport, actively develop green logistics. Coal from power plants is mainly supplied from abroad, so logistics is an important aspect of the operation of enterprises. In the transportation of coal, enterprises mainly use road and railway transportation methods, in reducing the damage caused by logistics to the environment at the same time, actively optimize the logistics environment, improve the utilization of logistics resources. Enterprises will be closely linked with logistics engineering, resource conservation and environmental protection as the primary goal, optimize the logistics system, in promoting forward logistics and reverse logistics green, to achieve the ultimate goal of sustainable development.

1.2. Green system constraints

The concept of "green" was put forward a long time ago, but the concept of "green development" was first put forward at the Fifth Plenary Session of the 18th Central Committee. A lot of green development policies were introduced. The National Law on the Prevention and Control of Air Pollution clearly states that the total amount of emissions of major atmospheric pollutants should be controlled, so the emission of pollutants from coal-fired power plants should be strictly in accordance with national standards. In June 2017, Huai'an City held a party committee with the concept of "ecological first, green development", which pointed out that the vigorous development of green industry, many enterprises are also for long-term development and active transformation. The State strictly controls the ecological red line, carried out the "Green Shield 2019" special action, and built an ecological red line environmental monitoring platform within the city. We will build a system of air quality monitoring and dust reduction monitoring "long points" and speed up the implementation of 241 annual key gas treatment projects. Stabilize and continuously promote the "263" operation, in accordance with the law to investigate and punish enterprises and groups of environmental violations. In order to obtain fairness and justice in order to prevent internal conflicts in the supply chain, the impact of these policy ideas on enterprises must be taken into account as a consideration for rational distribution.

2. The income distribution model is established

2.1. Distribution of benefits based on the shapley value method

Any subsystem in Supply Chain System I has a true value function V(S) that meets the following criteria:

$$V(\phi)=0 \tag{1}$$

$$V(S_1 \cup S_2) > V(S_1)+V(S_2), S_1 \cap S_2 = \phi \tag{2}$$

$[I,\ V]$ is the individual cooperative countermeasure n and the characteristic function of the countermeasure V. Formula (1) means that the enterprise does not participate in any system, so the cooperative profit is 0. As can be seen from formula (2), the total profit after the enterprise cooperation is greater than or equal to the sum of the profits of the enterprise alone. Everyone's cooperative alliance benefits from cooperation throughout the green supply chain, while in practice, alliances are opposed, i.e. the increase in the number of cooperation does

not diminish the overall interests of the entire cooperative alliance. That is, the overall benefits of the green supply chain will be maximized at this time.

The following conditions must be met when individuals form green supply chain cooperation.

1) Equivalent theorem: if insiders $i, j \subset N$, on any kind of cooperative alliance $S \subset N \setminus \{i, j\}$, then $V(S \cup \{i\}) = V(S \cup \{j\})$ then $\varphi_i(\mathrm{V}) = \varphi_j(V)$.

2) Effective theorem: If supply chain members do not contribute to the cooperative alliance, they will not be paid. If all contained subset S are $V(S/\mathrm{i}) = V(S)$, then the $\varphi_1(V) = 0$ φsum of the $\varphi_i(V)$ sekos in 1~n is equal to $V(N)$.

3) Add legal reason: When a person in an bureau participates in two cooperations at the same time, the overall distribution is the sum of the two. For any two feature functions in N V_1 and V_2, there is always $(V_1 + V_2) * (S) = V_1(S) + V_2(S)$ and $\varphi_i(V_1 + V_2) = \varphi_i(V_1) + \varphi_i(V_2)(V_1 + V_2) * (S) = V_1(S) + V_2(S)$.

In general, Xi is often used to represent the revenue that a company in Partner I deserves from the maximum benefit generated by a partnership. Based on I, the strategy of cooperation distribution is expressed $X = (X_1, X_2, X_3, \cdots, X_n)$.For a sub-collaboration to succeed, the following conditions must be met:

$$X_i \geq V(i), i = 1, 2, 3, \cdots n \tag{3}$$

$$\sum_{i=1}^{n} X_i = V(I) \tag{4}$$

These two styles have great practical significance, the formula (3) represents the rational conditions of individuals in cooperation, that is, the total benefits of enterprises through green supply chain cooperation should be greater than the total benefits of their own single work. The formula (4) means that the total distribution cannot be greater than the total benefit.

Shapley value: Suppose that M=[I,V] is a cooperative countermeasure of n individuals with and only one set of shapley values is

$$\prod_i(v) = \sum_{i \in s} \frac{(n - |s|)!(|s| - 1)!}{n!}[V(S) - V(S/i)] = \sum_{i \in s} W(|s|)[V(S) - V(S/i)], i = 1, 2, 3, \cdots, n \tag{5}$$

$\prod_i(v)$ is refers to the income that the third enterprise obtains from the supply chain cooperation; $|s|$ refers to the whole system containing the enterprise S. $V(S)$ refers to the total number of enterprises in system s. $V(S/i)$ the income of the system refers to the income of the system when the enterprise does not participate in the cooperation. From this, we can get the income $V(S) - V(S/i)$ that enterprises i bring when they participate in the cooperation of the system.

2.2. Distribution of benefits based on the shapley value method based on environmental contribution

The use of the shapley value method for the distribution of benefits between the three parties in the supply chain is carried out on the premise that the contribution of the three parties to the environment in the supply chain is equal, but in reality, this assumption is often difficult to achieve because of the different responsibilities of the three parties and the purpose for which the parties wish to maximize their respective interests. In the actual thermal coal supply chain, members in the environmental cost allocation of the contribution is different, and the parties may want to maximize their own earnings, and contrary to the original supply chain members signed a cooperation agreement, so as to hastely implement their own responsibility for environmental cost sharing, even at the expense of other enterprises, at the same time also harm the overall interests of the green supply chain of

thermal coal. Therefore, the distribution of revenue in the supply chain based on the shapley value method of environmental contribution can effectively promote members to fulfill their responsibilities of environmental cost sharing, prevent such irresponsible behavior, and ultimately promote the coordination, stability, sustained and healthy development of the thermal coal supply chain. Therefore, this paper based on the actual supply chain of the contribution of all parties to the environment to use the shapley value method to establish a reasonable income distribution model.

By measuring the relative degree of factors affecting the distribution of income between members of the green supply chain system, the benefit distribution model of the supply chain system is revised, and on this basis, a more scientific and reasonable income distribution system is obtained.

1) Using the Shapley Value Method, Calculate the income $\prod_i(\mathrm{V}), i=1,2,3,\cdots n$ of each enterprise from the green supply chain system.

2) Determine the contribution factors of each enterprise to the supply chain, such as the contribution factor of the i enterprise is ϕ i, wherein i is 1, 2,3…n. The sum of all enterprise contribution factors is 1, $\sum_{i=1}^{n}\phi i=1$

3) The difference between the contribution factor of the i enterprise to the supply chain $\Delta\phi_i$ and the average contribution $\frac{1}{i}$ of each enterprise is

$$\Delta\phi_i=\phi_i-\frac{1}{i},\sum_{i=1}^{n}\Delta\phi_i=0 \tag{6}$$

4) Taking into account the differences in environmental contributions between different enterprises, the distribution of benefits in the supply chain system should be compensated for by the contribution of each member. Compensation value: $\Delta Vi(S)=V(S)\times\lambda\Delta\phi$ i, λ for the adjustment factor, belongs to between 0 and 1. This value is determined by negotiation between the enterprises in the system. When the compensation value is greater than zero, it indicates that the enterprise's contribution to the supply chain is relatively high, so it should compensate the enterprise for the benefit when the income is distributed, on the contrary, if the negative number, the enterprise should be compensated for the negative income at the time of distribution of the income. So the benefits that members of the system i should actually get are:

$$\prod_i^{'}(\mathrm{V})=\prod_i(\mathrm{V})+\square V_i(\mathrm{S}) \tag{7}$$

3. Instance analysis

Taking the green supply chain of thermal coal operated by power plants as an example, this chapter studies the distribution of income from the thermal coal supply chain, taking into account the green constraints and contribution of the above-mentioned enterprises. Simplify the supply chain into Mine A, Power Company B, and third-party logistics company C. Therefore, the order $N\{(A,B,C)\}$ is a cooperative alliance of three enterprises.

1) V ('A') is 5 million yuan, V ('B') is 8 million yuan V('C') is 3 million yuan, for the three enterprises operating alone when the income. $\phi_A=0.2\ \phi_B=0.5\ \phi_C=0.3$ is the contribution level values of enterprises A, B and C to the green supply chain of thermal coal are respectively.

Enterprise A, B, C under the different combination of cooperation under the income is:

V（{A，C}）=9 million yuan,，V（{B，C}）=12 million yuan，V（{A，B，C}）=23 million yuan. V（{A，B}）=14 million yuan .

Thus, no matter what combination, the benefits of cooperation are greater than the sum of the benefits of the enterprise operating alone. Eligible for cooperative alliances, enterprises are willing to join the cooperative alliance.

2) After calculating the value method of shapley, the cost that enterprises A, B and C should share is represented by Table 1, Table 2 and Table 3 respectively.

Table 1: The shapley value of A for thermal coal suppliers

S	{A}	{A、B}	{A、C}	{A、B、C}
V（S）	500	1400	900	2300
V（S/{A}）	0	800	300	1200
V（S）v(S/{A})–	500	600	600	1100
| S|	1	2	2	3
W(| S|)	1/3	1/6	1/6	1/3
W(| S|) [V(S)V(S/{A–})]	500/3	100	100	1100/3
φ_A(C)		733.33		

Table 1: Shapley value of Huai'an Huaneng power plant

	{B}	{A、B}	{B、C}	{A、B、C}
V（S）	800	1400	1200	2300
V（S/{B}）	0	500	300	900
V(S)V(S/{B})–	800	900	900	1400
| S|	1	2	2	3
W(| S|)	1/3	1/6	1/6	1/3
W(| S|) [V(S)V(S/{B})]–	800/3	150	150	1400/3
φ_B(C)		1033.33		

Table 2: Shapley value of Transport Enterprise C

S	{C}	{A、C}	{B、C}	{A、B、C}
V(S)	300	900	1200	2300
V(S/{C})	0	500	800	1400
V(S)V(S/{C})–	300	400	400	900
| S|	1	2	2	3
W(| S|)	1/3	1/6	1/6	1/3
W(| S|) [V(S)V(S/{C})]–	100	200/3	200/3	300
φ_C(C)		533.33		

As can be seen from the table above, φ_A=7.3333 million, φ_B=10.3333 million, and φ_C=5.3333 million. And $\varphi_A + \varphi_B + \varphi_C$=23 million yuan. The benefits of the participation of enterprises in the cooperative alliance are greater than those earned when operating alone, and the sum of the profits earned by each enterprise is equal to the total benefits of the green supply chain of thermal coal. Therefore, enterprises will voluntarily participate in the green supply chain, to achieve multi-party cooperation and operation, and ultimately achieve mutual benefit and win-win situation.

3) Calculate the enterprise contribution weighting factor and the improved shapley value

According to the formula (6), the weighting factor of the enterprise's respective contribution can be calculated:

$$\Delta\phi_A = \phi_A - \frac{1}{i} = 0.2 - \frac{1}{3} = -0.1333$$

$$\Delta\phi_B = \phi_B - \frac{1}{i} = 0.5 - \frac{1}{3} = 0.1667$$

$$\Delta\phi_C = \phi_C - \frac{1}{i} = 0.3 - \frac{1}{3} = -0.333$$

According to the formula (7), the distribution value of each enterprise's income after the improvement of the sharery value on the basis of contribution is calculated. After three-way consultation, the selection of 0.3 as the adjustment factor.λ

$$\prod\nolimits_A^{'}(V) = \Delta V_A(S) + \prod\nolimits_A(V) = \lambda\Delta\phi_A \times V(S) + \prod\nolimits_A(V)$$
$$= 0.3 \times (-0.1333) \times 2300 + 733.33 = 641$$

$$\prod\nolimits_B^{'}(V) = \Delta V_B(S) + \prod\nolimits_B(V) = \lambda\Delta\phi_B \times V(S) + \prod\nolimits_B(V)$$
$$= 0.3 \times 0.1667 \times 2300 + 1033.33 = 1148.35$$

$$\prod\nolimits_C^{'}(V) = \Delta V_C(S) + \prod\nolimits_C(V) = \lambda\Delta\phi_B \times V(S) + \prod\nolimits_C(V)$$
$$= 0.3 \times (-0.1333) \times 2300 + 533.33 = 510.35$$

Organize and compare data before and after.

Table 4: Data before and after comparison

enterprise	Single profit	Shapley value	Improved shapley value
A	500	733.33	641.35
B	800	1033.33	1148.35
C	300	533.33	510.35

By comparison, it can be found that enterprises in the cooperation after the profit is higher than their own single-handedly obtained. This shows that through the cooperation of green supply chain, not only can enterprises get more profits, but also the efficiency of supply chain has been improved. Therefore, it is beneficial and correct to adopt green supply chain cooperation and development.

4. Conclusions

The problem of unreasonable distribution of supply chain income often brings many problems, and in the context of green sustainable development, the distribution of supply chain income becomes more complex. However, this paper gives the enterprise's contribution to improve the shapley value, and strive to establish a scientific and reasonable income distribution model. When an enterprise contributes more to a green supply chain than the average hour of the supply chain, we can modify its profits and reduce some of its profits accordingly. On the contrary, if the contribution is relatively high, it can also increase some of the profit. The benefit distribution model established by the contribution-based shapley value method can better coordinate the fairness of the distribution of income, so that enterprises can voluntarily join the supply chain.

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