Research on Benefit Distribution of Online Supply Chain Financial Alliance Based on the Cloud Center of Gravity Method

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Abstract: Benefit distribution is an important part of strengthening the development of supply chain financial alliances and building a community of interests sharing and risks sharing. Online supply chain finance is an innovative supply chain financial development model. Its participation involves banks, small and medium-sized financing companies, e-commerce platforms and logistics companies. How to handle their respective interests has a great research significance to promote online supply chain finance. Based on Shapley value method, this paper combines the effort, input level and risk factor to allocate the overall benefit of the online supply chain financial alliance by using the cloud center of gravity correction method. It is illustrated by example that this method can be used to obtain a much fairer return.

1. Introduction

Online supply chain finance (OSCF) is a specialized area of commercial bank credit business, a financing channel for SMEs, and an innovation in the financial business model. It is based on the long-term cooperative relationship between upstream and downstream companies in the supply chain. It integrates “funds flow”, “commercial flow”, “information flow” and “logistics”, consisting of financial institutions, SMEs, e-commerce platforms and logistics organizations. How to distribute the benefits is a vital issue in integrating the resources, earning the economic value of cooperation, and building an alliance of OSCF. However, currently, there are few studies about it, and the methods of distribution vary. Therefore, this paper aims to explore a reasonable distribution method of the overall benefit of the alliance, thereby strengthening the cooperation and stable development of the alliance, broadening the financing channels, and innovating comprehensive financial services, which will provide research ideas for improving the benefit sharing mechanism of OSCF.

2. Literature review

With information technology improvement, OSCF has expanded from traditional offline operation to online operation, which has pushed the efficiency of financing, but has increased the interest contradiction of participants. This has become a new research hotspot. Yet the existing research focuses on operational models and risk. It is lack of research on benefits distribution mechanisms.

OSCF's operating model can be summarized as bank-led, e-commerce-led and under the leadership of B2B e-commerce platform. The e-commerce-led model includes electronic warehouse receipts, electronic order financing between buyers and sellers [1], which helps to increase the participants quantity and financial innovation. Because OSCF is a combination of Internet finance and supply chain finance, it will be affected by various risk factors such as macroeconomic, credit level, technological advancement, and professional capabilities.

OSCF can generate direct and indirect benefits. Direct benefits include economic benefits and technical benefits of e-commerce platforms [2]. Overall benefits are affected by external factors, like macroeconomic, government support, electronic technology and financial supervision system; and affected by internal factors, like companies' development potential. From the perspective of the participants, bank is the main supplier of funds, providing financial products and services; SMEs are demanders of funds, needing to improve credit level and financing efficiency; the core enterprises, through transferring internal financing to upstream and downstream SMEs to help them obtain a fair financing platform and stable capital flow; e-commerce platform service providers play a central role in the collection and management of information, controlling the logistics, information flow and capital flow of upstream companies; third-party logistics companies provide asset warehousing, distribution and supervision. There are support institutions including rights registration organizations, regulatory and insurance companies. These participants cooperate with each other, which not only promotes OSCF's development, but also enhances their social values and economic levels.

Recently, researchers have used the Shapely value to study the profit distribution and have explored the interest relationship between two participants in traditional offline supply chain. In terms of benefit distribution ways, the related studies include: combining the AHP-GEM-Shapley method to study the innovation alliance in the field of low carbon technology and its evaluation index; using the cooperative game theory and Shapley to analyze the interest relationship of supply chain financing entities under the bilateral platform of logistics; using fuzzy cooperative game to distribute interests between alliances and to divide interests among participants within the alliance; studying the cloud center of gravity to corrects the coefficient of interest distribution of alliance members [3]; supporting the negotiation of technology innovation alliance to determine the income of each enterprise.

This article main studies the e-commerce-led model, and a method for improving the distribution of benefits based on Shapely values. The findings will provide a fair and reasonable solution for the benefits distribution of OSCF alliances and enrich new research perspectives.

3. Construction of income distribution model

3.1 Model design

Actually, the Shapley value method distributes income according to the contribution of the members themselves. It is often used to process the interests of economic activities, but it implies the assumption of equal risk sharing. Therefore, based on the Shapley value, this article combines the effort level and input cost of each member, and risk factors (like operational risk, credit risk, technical risk and market risk), and uses the cloud center of gravity method to divide whole benefits. The method is the cross-infiltration of traditional fuzzy set theory and probability theory. The cloud model uses linguistic values to represent the fuzzy transformation model between qualitative indicators and quantitative indicators, which can effectively process fuzzy information, obtain quantitative reference, solve subjective evaluation and randomness problems. And it is a better expression of data uncertainty and expert knowledge.

3.2 Model construction

3.2.1 General model of the Shapley value

Under certain conditions,$\mathrm{L} = \{1,2,\dots,\mathrm{n}\}$ is a collection of n partners. If there is any subset $\mathrm{u} \subseteq \mathrm{L}$, there is a real number $\mathrm{v(u)}$ corresponding to it. U represents an alliance of n partners, and $v(U)$ represent the maximum benefit that U obtains. In any case, cooperation is at least more advantageous than cooperation between single or small groups. The strategy of cooperation is to clarify the benefits $\varphi_i(v)$ obtained by each member or for the whole person is vector: $\varphi(v) = (\varphi_1(v), \varphi_2(v), \dots, \varphi_n(v))$, a reasonable allocation needs to satisfy: $\sum_{i\in U} \varphi_i(v) \geq v(U)$, and the

equal sign is established when $U = L.\varphi(v)$ is the only solution, and its formula is: $\varphi_i(v) = \sum_{u \in U_i} \omega(|u|)[v(u) - v(u/\{i\})]$.

Where U_i is the set formed by all subsets of member i in L, $|u|$ is the number of elements of the set U, and $\omega(|u|)$ is the weighting factor, $\omega(|u|) = \frac{(|u|-1)!(n-|u|)!}{n!}$, and $v(u) - v(u/\{i\})$ is the contribution of member i in the cooperation U he participated in.

3.2.2 Risk factors

Because the weight of the risk factor index of the e-commerce platform has fuzzy features, it can be combined with the fuzzy comprehensive evaluation method and analytic hierarchy process. This method can better solve the fuzzy and quantitative problems and evaluate the target according to various factors. Specifically, in conjunction with the will of the expert group, a weight vector can be constructed for each risk factor through the hierarchical analysis process, and a judgment matrix can be given. Therefore, the risk factors of each affiliate entity are obtained and normalized, that is:$R=\{r_1, r_2, r_3, r_4\}, \sum_{i=1}^{n} r_i = 1$.Add risk correction factor:$1 + \Delta n = 1 + (r_i - \frac{1}{n}), i = 1,2, \dots, n$, and Δn represents the actual income allocation correction for each member, so the member i can earn income as:$\varphi_i(v)' = \varphi_i(v)(1 + \Delta n) = \varphi_i(v)\left[1 + \left(r_i - \frac{1}{n}\right)\right], i = 1,2, \dots, n.$

3.2.3 Cloud center of gravity method

The model is characterized by three numerical features, namely the expected value (Ex), the entropy (En) and the super-entropy (He), Ex represents the information center value of the fuzzy concept, En represents the number of elements acceptable for the fuzzy concept, and He represents the degree of dispersion of the cloud. The center of gravity of the cloud is the result of multiplying the position of the cloud center of gravity and the height of the cloud center of gravity. When this position is fixed, the size of the cloud center of gravity is positively correlated with its height. The change of this cloud center can reflect the change of the state of the system and the deviation between the obtained result and the ideal state, which can help correct the results.

Firstly, establish an indicator system for evaluation targets and weights for each indicator. Determine the evaluation cloud, which is represented by its three characteristics as(Ex, En, He), and determine the expert set $P = \{P_i / i = 1,2, \dots, t\}$, the comment set $R = \{R_j / j = 1,2, \dots, m\}$, and the number of t experts give the interval values of each comment, recorded as $C_{ij} = [a_{ij}, b_{ij}]$, a_{ij}, b_{ij} are between $[0,1]$, and constitutes a judgment matrix. The number of intervals corresponding to each comment is collected and averaged to obtain the number of clouded intervals, which is denoted as:

$C_j = \frac{1}{t}\sum_{i=1}^{t} C_{ij} = [a_{j-1}, a_j], j = 1,2, \dots, m.$

Then, the clouded interval number is converted into a cloud model, and the expectation vector of a certain indicator cloud model is assumed to be $Q = (E_{x_1}, E_{x_2}, \dots, E_{x_t})$, and the entropy vector is assumed to be $(E_{n_1}, E_{n_2}, \dots, E_{n_t})$. The expectation and entropy of the quantitative indicator cloud model are expressed as follows:

$$E_x = (E_{x_1} + E_{x_2} + \cdots + E_{x_n}) / t \tag{1}$$

$$E_n = \frac{\max(E_{x_1}, E_{x_2}, \dots, E_{x_n}) - \min(E_{x_1}, E_{x_2}, \dots, E_{x_n})}{6} \tag{2}$$

The expectation and entropy of the qualitative indicator cloud model are:

$$E_x = (E_{x_1}E_{n_1} + E_{x_2}E_{n_2} + \cdots + E_{x_t}E_{n_t}) / \left(E_{n_1} + E_{n_2} + \cdots + E_{n_t}\right) \tag{3}$$

$$E_n = E_{n_1} + E_{n_2} + \cdots + E_{n_t} \tag{4}$$

If multiple indicators are involved, it is represented as a multi-dimensional integrated cloud, and the multi-dimensional cloud center of gravity is represented as a vector $T = (T_1, T_2, T_3, T_4)$, and $T_i = a_i \times b_i$,a_i represents the expected value of the i index cloud model, and b_i represents the normalized weight of the indicator cloud model.

The ideal cloud center of gravity is denoted by $T' = (T_1', T_2', T_3', T_4')$, and $T_i' = a_i' \times b_i$, a_i' is the expected value of the indicator under ideal conditions. The multidimensional cloud center of gravity vector T is normalized to obtain $T^0 = ({T_1}^0, {T_2}^0, {T_3}^0, {T_4}^0)$, and the formula is as follows:

$$ {T_i}^0 = \begin{cases} \frac{T_i - T_i'}{T_i'}, T_i < T_i' \\ \frac{T_i - T_i'}{T_i}, T_i \geq T_i' \end{cases} \tag{5} $$

Further, the weighted deviation of the cloud center of gravity can be calculated as:

$$ \theta = \sum_{i=1}^{n} \left(\omega_i {T_i}^0 \right), (-1 < \theta < n) \tag{6} $$

Where ω_i is weight value of each indicator. The cloud's center of gravity deviation can measure the difference between multi-dimensional clouds and the ideal state of it. The smaller the value, the better.

By normalizing the weighted deviation θ to θ^*, the profit correction values of each participating subject can be obtained as follows: $\Delta\varphi(v) = \mathrm{v}(n) \times (\frac{1}{n} - \theta^*)$,

$\frac{1}{n} - \theta^*$ represents the weight of the benefit revision of each participant, and $\mathrm{v}(n)$ indicates the benefit in the case of cooperation, so the benefits that participant i can allocate are:

$$ \varphi_i(v)' = \varphi_i(v) + \Delta\varphi_i(v) \tag{7} $$

Therefore, based on various influencing factors, the benefit distribution result is closer to the ideal state.

3.3 Example

Analyze an OSCF alliance led by an e-commerce and use the cloud center of gravity method to distribute benefits based on Shapley value. The alliance is recorded as $U = \{A, B, C, D\}$. The members are financing enterprise (A), commercial bank (B), e-commerce platform enterprise (C) and logistics enterprise (D). The result of distribution is recorded as $\varphi_A(v), \varphi_B(v), \varphi_C(v), \varphi_D(v)$. Each entity obtained independently income of 150,000, 300,000, 250,000 and 200,000; 600,000 yuan for AB cooperation, and 450,000 yuan for AC cooperation, AD won 500,000 yuan, BC received 600,000 yuan, BD get 700,000 yuan, CD get 550,000 yuan; ABC earn 900,000, ABD earn 1.1 million, ACD earn 1 million, BCD earn 1.2 million; and the four entities cooperated to earn 1.8 million. If the total benefit of joint cooperation is distributed on average, each member can get 450,000 yuan. Although it is higher than the operate independently profit, it lacks certain fairness. Thus, the above-mentioned cloud center of gravity method is adopted to calculate.

3.3.1 Analysis of factors

The level of risk management ability of participants is closely related to how much effort and investment in cooperation. The more effort, the closer the partnership, the higher trust in the alliance, and the more benefits participant get from cooperation. The input cost reflects the willingness and contribution of each entity to the alliance, including the costs of cooperation,

supervision and reputation. This article will provide a comprehensive analysis of risk factors, input and effort lever.

3.3.2 Distribution of income

The three influencing factors of risk factor, input cost and effort level are regarded as three-dimensional integrated cloud, and the cloud center of gravity vector is $T = (T_1, T_2, T_3)$, $T_i = a_i \times b_i$, where a_i represents the expected value of the i indicator and b_i represents the normalized weight of the indicator. The evaluation set is expressed as:

$V = \{0.1, 0.3, 0.5, 0.7, 0.9\} = \{low, low, medium, high, high\}$, reflecting the importance level of indicator, that is, the expected value. Ten experts were invited to evaluate the three indicators of each participating member. The financing enterprise A is taken as an example. The four sets of samples for extracting indicators are shown in Table 1, and the index weight is determined as $\omega = (0.083, 0.193, 0.724)$. The ideal state of the supply chain alliance system is determined as $T' = (1, 1, 1)$, indicating that in general, the greater risk faced by members, the more inputs and efforts, the greater contribution to the business, and the higher benefits. According to equations (1) and (2), the expected value and entropy of each indicator cloud model can be expressed as Table 2.

Table 1. Evaluation values of various indicators of financing enterprises A

Evaluation sample	Risk factor	Input	Effort level
1	0.6	0.6	0.8
2	0.5	0.5	0.7
3	0.3	0.4	0.6
4	0.4	0.5	0.6
Ideal value	1	1	1

Table 2. Expected value and entropy of the financing enterprise A cloud model

Index	Risk factor	Input costs	Effort level
Ex	0.450	0.500	0.675
En	0.050	0.033	0.033

Through calculation, we can get the cloud center of gravity of the three-dimensional integrated cloud of the financing enterprise A: $T = (0.037, 0.097, 0.489)$, and the ideal result is: $T' = (0.083, 0.193, 0.724)$. According to formula (5), normalizing the cloud center of gravity vector, we can get: $T^0 = (-0.554, -0.497, -0.325)$. According to formula (6), the cloud center of gravity deviation can be calculated, that is, the weighted deviation from the ideal state: $\theta_A = -0.377$.

In the same way, the deviation of the three-dimensional integrated cloud of commercial bank B, e-commerce platform C and logistics enterprise D can be calculated respectively: $\theta_B = -0.390, \theta_C = -0.397, \theta_D = -0.477$.

By normalizing the deviation, it can be concluded that: $\theta_A{}^* = 0.230, \theta_B{}^* = 0.238, \theta_C{}^* = 0.242, \theta_D{}^* = 0.290$.

Calculate the correction value of the benefit, and then according to formula (7), the result can be obtained:

$$\varphi_A(v)' = \varphi_A(v) + \Delta\varphi_A(v) = 35 + 180(0.25 - 0.230) = 38.6$$
$$\varphi_B(v)' = \varphi_B(v) + \Delta\varphi_B(v) = 52.5 + 180(0.25 - 0.238) = 54.66$$
$$\varphi_C(v)' = \varphi_C(v) + \Delta\varphi_C(v) = 42.5 + 180(0.25 - 0.242) = 43.94$$
$$\varphi_D(v)' = \varphi_D(v) + \Delta\varphi_D(v) = 50 + 180(0.25 - 0.290) = 42.8$$

From the results, it is known that the cloud center of gravity correction allocation method is more reasonable. After analysis, compared with the benefits obtained by the original Shapley value method, borrowers, commercial banks and e-commerce platform companies have increased their profits under the cloud focus method.

4. Conclusion

Based on the Shapley value method, this article introduces risk factors, effort and input levels, and uses the cloud center of gravity method to distribute the overall benefits of alliances of OSCF. It is proved by example that the method can comprehensively consider different factors and be fair. The study provides a solution for coordinating the cooperation relationship between the interests of online supply chain alliances, provides ideas for innovative OSCF development, and promotes the comprehensive services of information flow, logistics, capital flow and business flow to a certain extent. The research has practical significance.

According to analysis, in order to establish a better harmonious ecosystem of OSCF, all participating entities should make contributions to their efforts. Financial institutions should improve risk management abilities, credit ratings, loan review and supervision procedures; e-commerce platforms should enhance information communication and processing capabilities to ensure operational efficiency between companies; core enterprises should innovate management and increase capital and technology investment; SMEs should improve their business structure and ease financing pressure. In addition, this research and the method still need to be further improved, and the application of the method in the specific model needs to be analyzed in detail. Future research can explore innovative services and risk management of OSCF in conjunction with the Internet, the Internet of Things, and big data to make relevant results in this research area.

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