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Profit Distribution Strategy Model in the Three-level Supply Chain Based on the Cooperative Game Theory

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Abstract: Aiming at the three-level supply chain, this passage focus on how to distribute the profit of supply chain under a centralized strategy fairly and reasonably, as well as build up an effective strategy model of supply chain profit allocation based on cooperative game theory and figure out the Shapely value of the benefit distribution. Besides that, the Shapely value could be modified according to the relevant factors of the benefit allocation of the joint enterprises so that it can work out the problem of distributing profit effectively and reasonably in the supply chain. In addition, it is obvious to optimize the interest of the whole supply chain as well as maximize the partial interest of the joint enterprise, thus, promoting and maintaining the operation of supply chain effectively and steadily.

Key words: Supply chain, cooperative game, profit distribution, shapely value method

INTRODUCTION

The supply chain (Simatupang *et al*., 2002), as a whole, is generally comprised of numerous independent economic entities. The overall interest derives from the sincere cooperation of the joint enterprises. It is wise to coordinate the supply chain (Giannoccaro and Pontrandolfo, 2004) in order to operate effectively and steadily. Thus, the whole profit of the supply chain among these cooperative corporations (Giannoccaro and Pontrandolfo, 2004) could be distributed more fairly and reasonably, as well as the operation could be promoted more stably in the long run. It is known to us that the profit of the supply chain system varies with the level of the alliance of joint enterprises in the supply chain. The higher the level is, the more the profit is. In order to make the operation of the supply chain system more efficiently and steadily in the long run, the profit need to be assigned equally, justly and reasonably. As we can see, the interest of the supply chain system is primarily allocated by the Shapely value method of the cooperative game theory. In addition, the Shapely value (Forrester, 1958) is modified for the differences of the cost input, risk exposure and contribution of the joint entities, so that the profit of the supply chain system among the joint entities could be allocated more reasonably.

Profit analysis of the three-level supply chain game enterprise: The whole profit will be increased (Cachon and Lariviere, 2005) in the supply chain when the joint enterprises are collaborating, thus, the reasonable distribution of the interest to maintain the efficient and steady operation has become the main problem to be solved. The proper order of the supply chain from the senior level to the junior level is supplier(s), manufacturer (m) and retailer(r).

For the three-level supply chain alliance (Gang *et al*., 2009), the member of each level can only ally itself with the adjacent member. Therefore, there are four kinds of relationships of alliances:

- Supplier(s), manufacturer (m) and retailer(r) don't combine with each other at all, they are making decisions independently. A record is kept of [s, m, r]
- Supplier(s) and manufacturer (m) join in cooperation, while the retailer doesn't take part in any alliances. A record is kept of [(s, m), r]
- Manufacturer (m) and retailer(r) join in cooperation, while the supplier doesn't take part in any alliances. A record is kept of[s, (m, r)]
- Supplier(s), manufacturer (m), retailer(r) join in cooperation, making a centralized decision. A record is kept of [(s, m, r)]

If each joint entity's profit is lower than the interest of noncooperation or part-cooperation when the enterprises come to alliances, the strategy (Xuecheng and Wentao, 2008) will not be accepted by each joint cooperation. In order to gain more profit as well as to promote the implementation smoothly, the interest of each joint firm must be promised not lower than the profit of noncooperation or part-cooperation. Therefore, a profit distribution strategy which is facilitated for daily manipulating should be set up, so that the supplier, manufacturer and retailer could share the increased profit derived from the system.

The interest of the supply chain varies (Yande and Bangyi, 2008) with the different alliance situations and under each alliance situation, the profit of the supply chain is the foundation of the profit distribution which is operated by the Shapely value method. As the interest is redistributed, the profit of some firms will be increased while others will be decreased. If the distribution is beyond the rational boundary, the cooperative relationship among the supply chain will break up. Thus, some relevant factors such as the profit, the price, the products quantity and etc. under different cooperative situations need to be compared and analyzed, through which the interest could be distributed smoothly.

There are four main patterns for the alliances of the three-level supply chain joint enterprises (Yande and Bangyi, 2009), which determine the profit variation of the supply system by its nature and to a large extent, the increase of the profit will promote the cooperation's stability of the member enterprises. By analyzing the key points such as the decentralized decisions of member entities in the supply chain (Meirong and Yan, 2009), the alliance decisions of the partial joint enterprises and the profit variation of the member enterprises under a centralized policy in the supply chain system, a conclusion can be drawn that the profit in the supply chain system can be maximized under the centralized decisions. In addition, a proper contract selection is analyzed to allocate the profit reasonably, which can assist the corporations in building the cooperative relationship in the supply chain.

Strategy model and solutions of the profit distribution in the supply chain

Basic description of the cooperative game: The model of the profit distribution in the supply chain (Shihua and Peng, 2006) is described as follows: firstly, suppose a supply chain comprised of joint enterprises with the number of n, recorded as set $N = \{1,2...n\}$, then call any S in the 2n subsets an alliance in N; Besides, v is defined as a Real Function in the 2n alliances, called eigenfunction. The equation can be described as follows:

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

$$V(S \cup T) \geq V(S) + V(T), S \cap T = \phi \tag{2}$$

A formation of the formal eigenfuncion (Shengqiang *et al*., 2009) by the definition is the characteristic of the game. S is a subset of N's alliance, indicating the association of the members. With the definition of the maximized value of common interests for the member firms V(S), namely when the members with the number of N-S, adopt the alliance strategy of the least favorable combination for the coalition S, the coalition S could coordinate the strategy of its members to maximize the value of V(S). The equation can be expressed as:

$$V(S) = \max_{X \in X_{S_i}} \min_{Y \in Y_{N-S}} \sum_{i \cup S} v_i(X,Y)$$

where, v_i (X, Y) represents the gains of the members i in the alliance S, besides that, X, Y, respectively represent the combination of the strategy selected by each member of N and N-S.

Without regard to the outside causes, more coalitions will be built up by the members in the course of the cooperative game; therefore, the gains derived from the alliances should be distributed more reasonably to the members. Each member in the supply chain can effectively reduce the cost of components and finished products (Ruozhen and Xiaoyuan, 2006) as well as enhance the sales volume through the integration optimization of the core competence, in order to create more profit for the overall supply chain. As it can see, the corporation in the supply chain is an independent economic entity, which is risk-neutral and totally rational. As the Double Marginalization Effect in the decentralized decision makes the interest in the supply chain system modest, only by the two sides' cooperating can the profit be maximized in the supply chain and only by distributing the profit reasonably can the cooperation be preceded persistently in both sides. A conclusion can be drawn (Jiaguo and Chong, 2010) that the problem of the profit distribution in the supply chain's members can be seen as the problem of the interest allocation within members' cooperation.

Model specification: Firstly, suppose a cooperation game G = [N, v] with the member of n, having the character of abnormally high additively. If the order of the n participants in N is the (1, 2,..., n), the program distribution is considered as follows:

$$\begin{aligned} x_1 &= v(\{1\}) \\ x_2 &= v(\{1,2\}) - v(\{1\}) \\ &\cdots\cdots \\ x_n &= v(\{1,2,\cdots,n\}) - v(\{1,2,\cdots,n-1\}) \end{aligned} \tag{3}$$

Namely, the sequence is ranked by the natural order of the participants' numbers, besides that, the coalition is built up by the sequence stepwise and what the participants gain is the contribution margin for the alliances. Obviously, we can see the results:

$$\sum_{i=1}^{n} x_i = v(N) \tag{4}$$

A natural number is given to each participant in n of N, differing from each other, so there are n! ways of the sequence methods for n participants, therefore, it indicate that there are n! kinds of allocation plans. A participant's average contribution margin in the distribution plans of n! is:

$$\varphi_i(v) = \sum_{S_i \subseteq N} \frac{(n-|S|)!(|S|-1)!}{n!}[v(S) - v(S \setminus \{i\})] \quad i = 1, 2, \cdots, n \tag{5}$$

It should point (Qing-Hua, 2010a) that S_i is the all subsets comprised of enterprises i in the set N, besides, n means the numbers of members; |S| represents the numbers of the participants in the alliance S, in addition, (|S|-1) implies the coalition arrangement numbers without the participant i; (n-|S|)! is the coalition arrangement numbers without S, as n! means the arrangement numbers of the n participants:

$$\frac{(n-|S|)!(|S|-1)!}{n!}$$

indicates the occurrence probability of the alliance S, meanwhile v(S)-v(S\{i}) shows the participant i' s contribution margin for the coalition S. If $i \notin S$, that means v(S)-v(S\{i}) is 0.That is to say the participant i makes no contribution to the coalition S, no contribution margin either. Based on Shapely value profit distribution method (Weiying, 2004), the contribution of the overall coalition made by each participated enterprises is considered. The more contribution is, the more distribution can be achieved, and the opposite is the less contribution is, the less distribution can be attained. This indicates the independent's importance in the group. In this equation, s_i is the all subsets in N including i and |s| implies the member numbers in the subsets, meanwhile $\omega(|s|)$ represents the weighting factor. In fact, Shapely value method is a calculation exempting the probability (Dong *et al*., 2008). If the participants form the coalition S of the supply chain randomly, the occurrence probability of each coalition's in sequence is 1/n!. The coalition S in the supply chain is formed by the participant i and the former (|s|-1) members, then i's contribution to the alliance is [v(s)-v(s/i)] (namely the contribution margin). As the sequences formed stepwise by the members of (S/i) and N/S are (n-|s|)!(|s|-1)! kinds, the occurrence probability of each sequence's is (n-|s|)!(|s|-1)!/n!.

From the fact discussed above, it is obvious that the contribution expectation value of the participants for the alliance (Hou, 2004) means the participants' corresponding Shapely value. The ontribution margin that each member devotes to the alliance in the supply chain is allocated according to Shapely value method, which, to some extent, indicates the reasonableness and fairness of the profit distribution.

Profit distribution strategy of the supply chain based on shapely value method: The designers optimize the decisions in four different alliance methods, analyzing the profit variation of the supply chain system. A conclusion can be drawn (Haijun *et al*., 2009) that under the centralized decisions, the profit of the joint entities in the supply chain system can be maximized. It is needed to distribute the profit of the supply chain system fairly and reasonably for the three joint enterprises, which can mobilize the cooperation enthusiasm of the members, as well as promote the operation of the supply chain efficiently and steadily.

For a three-level supply chain (Flam and Jourani, 2009) composed of s, m, r, there are four ways to participate in the alliances for each entity. Once an alliance is formed, whether the other enterprises cooperate or not, the formed alliance is promised to gain the maximized profit in the supply chain system. In order to have a intuitionist result, the parameters are supposed as follows:

$$\frac{D - \alpha(C_s + C_m + C_r + \Delta C_4)}{\sqrt{\alpha}} = A, \ \Delta C_i = 0, \ i = 1,2,3,4$$

The Shapely value method (Chen *et al*., 2000) is applied to distribute profit of the supply chain system under the centralized decision made above and the primary allocating results are as shown as the Table 1 to 3.

From the tables above, the profit distribution of the joint entities in the supply chain are:

$$\begin{aligned} \phi_s(v) &= A^2/48 \times \frac{1}{3} + A^2/64 \times \frac{1}{6} + A^2/96 \times \frac{1}{6} + A^2/16 \times \frac{1}{3} \\ \phi_m(v) &= A^2/96 \times \frac{1}{3} + A^2/96 \times \frac{1}{6} + A^2/128 \times \frac{1}{6} + 11A^2/192 \times \frac{1}{3} \end{aligned} \tag{6}$$

$$\phi_r(v) = A^2/192 \times \frac{1}{3} + A^2/384 \times \frac{1}{6} + A^2/192 \times \frac{1}{6} + A^2/24 \times \frac{1}{3} \tag{7}$$

Table 1: Profit calculation procedure of the joint entities suppliers in the supply chain

S i = s	s	S∪m	S∪r	s∪m∪r
v (S)	$A^2/16$	$A^2/8$	$5A^2/64$	$A^2/4$
v (S\{i})	0	$A^2/32$	$A^2/64$	$A^2/16$
v (S)-v (S\{i})	$A^2/16$	$3A^2/32$	$A^2/16$	$3A^2/16$
i	1	2	2	3
$\frac{(n-\|S\|)!(\|S\|-1)!}{n!}$	1/3	1/6	1/6	1/3
$\frac{(n-\|S\|)!(\|S\|-1)!}{n!}[v(S) - v(S \setminus \{i\})]$	$A^2/48$	$A^2/64$	$A^2/96$	$A^2/16$

Table 2: Profit calculation procedure of the joint entities manufactures in the supply chain

S i = m	m	S∪m	S∪r	S∪m∪r
v (S)	$A^2/32$	$A^2/8$	$A^2/16$	$A^2/4$
v (S\{i})	0	$A^2/16$	$A^2/64$	$5A^2/64$
v (S)-v (S\{i})	$A^2/32$	$A^2/16$	$3A^2/64$	$11A^2/64$
i	1	2	2	3
$\frac{(n-\lvert S\rvert)!(\lvert S\rvert-1)!}{n!}$	1/3	1/6	1/6	1/3
$\frac{(n-\lvert S\rvert)!(\lvert S\rvert-1)!}{n!}[v(S)-v(S\setminus\{i\})]$	$A^2/96$	$A^2/96$	$A^2/128$	$11A^2/192$

Table 3: Profit calculation procedure of the joint entities retailers in the supply chain

S i = r	r	S∪m	S∪r	S∪m∪r
v (S)	$A^2/64$	$5A^2/64$	$A^2/16$	$A^2/4$
v (S\{i})	0	$A^2/16$	$A^2/32$	$A^2/8$
v (S)-v (S\{i})	$A^2/64$	$A^2/64$	$A^2/32$	$A^2/8$
i	1	2	2	3
$\frac{(n-\lvert S\rvert)!(\lvert S\rvert-1)!}{n!}$	1/3	1/6	1/6	1/3
$\frac{(n-\lvert S\rvert)!(\lvert S\rvert-1)!}{n!}[v(S)-v(S\setminus\{i\})]$	$A^2/192$	$A^2/384$	$A^2/192$	$A^2/24$

Influential factors of the profit distribution strategy in the supply chain: The stable profit of the cooperative enterprises in the supply chain (Li *et al*., 2009), namely the stable factors, is influenced by the interest achieved of corporation's investment and by whether it is independent or not. Meanwhile the extra profit, namely the flexible factors is influenced by the contribution and risks of the enterprise.

Input factors: The fixed investment and the operating cost investment are included in the total investment (Xiaoquan, 2007). As for the fixed investment, it begins when the enterprise takes part in the supply chain, while the operating cost forms when the participated corporation invest for the business cost in the operational process of the supply chain. Therefore, the start-up capital, human capital and the intangible assets and etc. are included in the input factors of the supply chain's membership enterprises.

In general, the input value of the supply chain's members will be measured by the proportion that how much the value of the input factors in the supply chain enterprises take up of the overall members' investment according to the literature (Tang *et al*., 2004). But for the contribution and the importance of all kinds of investment for the supply chain are different, the measurement of the resource investment needs to be assessed with the importance of the input factors. Suppose that a_{ij} means the value of the input resource by member, meanwhile i, i = 1, 2, 3, j = 1, 2, 3:

$$A_{3\times3}=\begin{pmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{pmatrix} \tag{8}$$

The c_j represents the importance level of j resource to the created value of the supply chain system and:

$$\sum_{j=1}^{3} a_{ij} * c_j$$

indicates the investment value of the created value by the membership enterprise i in the supply chain system.

The investment proportion of each entity in the supply chain can be calculated as the equation:

$$\lambda_i^1=\frac{\sum_{j=1}^{3} a_{ij}c_j}{\sum_{i=1}^{3}\sum_{j=1}^{3} a_{ij}c_j} \tag{9}$$

From their own perspective of each member, what is the most essential is to strive for the maximized profit for themselves, as well as claiming to invest for the resource of the supply chain. Therefore, is given by the experts grading method of the supply chain.

Contributing factors: The contribution of the joint enterprises for the whole supply chain is mainly reflected by the following fact: the business efficiency is enhanced and the trade cost is lowed down. Meanwhile, the stock level is reduced and the production cycle time is shortened. Besides, the serve level is improved. Moreover, the enterprises' profit is enhanced as well as the customer value. Therefore, the products and serve based on a quick respond to market can be provided for the clients and the enhanced profit of the overall supply chain will be shifted by the performance.

To calculate the contributing factors (Hu *et al*., 2008), as for the contribution of the enterprises to the supply chain cannot be measured by quantities, the factors such as market reactive speed, trade efficiency, the profit in the supply chain, the shorten time of the production cycle and the cut down of the business cost, are determined by AHP, in order to calculate the influenced weight of the contribution factors in the supply chain $\beta = (\beta_1, \beta_2, \beta_3, \beta_4, \beta_5)$.

The grades are made by the experts for their importance contrast level and a judgment matrix can be evaluated as follow:

$$B=\begin{pmatrix} b_{11} & b_{12} & b_{13} & b_{14} & b_{15} \\ b_{21} & b_{22} & b_{23} & b_{24} & b_{25} \\ b_{31} & b_{32} & b_{33} & b_{34} & b_{35} \\ b_{41} & b_{42} & b_{43} & b_{44} & b_{45} \\ b_{51} & b_{52} & b_{53} & b_{54} & b_{55} \end{pmatrix} \tag{10}$$

Making a single-level arrangement for B, then the consistency check should be conducted, until the results conform to the requirement of the consistency check. As for there are only two level of the hierarchical (Jingyan and Peiqing, 2008), so the overall rank do not need to be done. Thus, the normalized eigenvector which is corresponded with B is the weight vector $\beta = (\beta_1, \beta_2, \beta_3, \beta_4, \beta_5)$. The contribution rate of the supply chain can be directly demonstrated by the ratio of the ordering quantity of each corporation. Suppose that the ordering quantity of the ith enterprise is q_i, then the proportion it takes up of the whole supply chain is:

$$q_i / \sum_{i=1}^{n} q_i$$

Grades are made for the other four factors by the relevant experts with the number of m, based on the principle that how important the contribution factor is for the combined supply chain. The grades range from 0 to 1.Then suppose that the set of comments v = {less, little, modest, big, bigger}, the corresponding factors are v = {0.1, 0.3, 0.5, 0.7, 0.9}. Based on the principles above, the experts grade the contributing factors for each enterprise. Assume the tth factor (t = 1, 2, 3, 4) for the ith corporation and the grades d^t_{ij} are made by the jth expert. Then, the metric:

$$d^i_t = \sum_{j=1}^{m} d^t_{ij} / m$$

in the ith enterprise by the tth contributing factor can be calculated and the vector $d_t = \{d^1_t, d^2_t, d^n_t\}$ can be evaluated. At last normalize the vector and the result can be figured out as follow: $d^*_t = \{d^{*1}_t, d^{*2}_t, d^{*n}_t\}$. So, the contributing factor C_i can be worked out:

$$C_i = (\beta_1, \beta_2, \beta_3, \beta_4, \beta_5)^T . (q_i / \sum_{i=1}^{n} q_i, d^{*i}_1, d^{*i}_2, d^{*i}_3, d^{*i}_4) \quad (11)$$

Risk factors: In fact, under the changing environment, the supply chain and the members will inevitably undertake various kinds of risks (Xiang *et al*., 2008). Thus, the risk is analyzed in order to have a profit distribution strategy more reasonably in the supply chain. Therefore, the risk of the market, the risk of the partners' competence, the risk of the cooperative scope, the risk of information technology and safety and the risk of policy are considered in the environment analysis of supply chain.

Assume R_{ij} represents the jth risk which the ith member suffers and i = 1, 2, 3, j = 1, 2, 3, 4, 5. Besides that, the venture factors are the risk of market, the risk of the partners' competence, the risk of the cooperative scope, the risk of information technology and safety and the risk of policy, indicated by $U = \{U_1, U_2, ..., U_5\}$. Meanwhile the corresponding weight is $A = (\alpha_1, \alpha_2, ..., \alpha_5)$. The evaluation set M = {none, lower, low, modest, high, higher} and the value is endowed as M = {0, 0.1, 0.3, 0.5, 0.7, 0.9}. R_{ij} can be assessed by fuzzy comprehensive evaluation, in addition, the experts from the joint entities consist the risk assessment team, evaluating the five risk factors from the given evaluation set M, remarking the membership degree between the factors and the risks (Li *et al*., 2010). Thus, the fuzzy relation matrix B^i_{56} is calculated from U to M as follow:

$$D^i = A \cdot B = (\alpha_1, \alpha_2, ... \alpha_5) \begin{bmatrix} b^i_{11} & b^i_{12} & \cdots & b^i_{16} \\ b^i_{21} & b^i_{22} & \cdots & b^i_{26} \\ \vdots & \vdots & \ddots & \vdots \\ b^i_{51} & b^i_{52} & \cdots & b^i_{56} \end{bmatrix} = \left[d^i_1, d^i_2, ... d^i_6 \right] \quad (12)$$

Firstly, normalize the component of D, represented by D^i and then calculate the risk coefficient of the joint entities in the supply chain, which is $R_i = D^i.M^T$. In addition, normalize the risk coefficient of each member, as well as figure out the risk factors of the member i in the supply chain as follow:

$$\lambda^2_i = R_i / \sum_{i=1}^{3} R_i \quad (13)$$

Modification in Shapely value method of the profit distribution strategy model in the supply chain: A modified Shapely value, including the overall factors (Xin *et al*., 2011), can represent the principles of the cooperative game profit distribution more efficiently. Namely "Undertake the risk and share the profit together", "The more work, the more gain", "The pay and gain are on the equity". By conducting these measures, the profit distribution in the supply chain can be more scientific, reasonable and fair. Thus, the operation of the coalition can be more efficient and steady in the long run.

First of all, suppose the supply chain coalition $N = (x_1, x_2, ..., x_n)$ is comprised of n entities (Qing-Hua, 2010b) and the total profit produced under the centralized decision is v(N). Meanwhile, based on the Shapely value method, the profit share of the enterprise i is figured out as $\phi_i(v)$, however, it is limited with the method, for the fact that the risk factors, the fund investment and the contributing factors are not considered in the centralized decision among each joint entity. Therefore, a modified factor which influences the overall profit distribution could be drawn with regard to the former elements (Cachon and Lariviere, 2005), which is integrated in the Shapely value model and the modified interest allocation strategy can be obtained. The factors influencing the profit distribution in the supply chain system is shown as the Fig. 1.

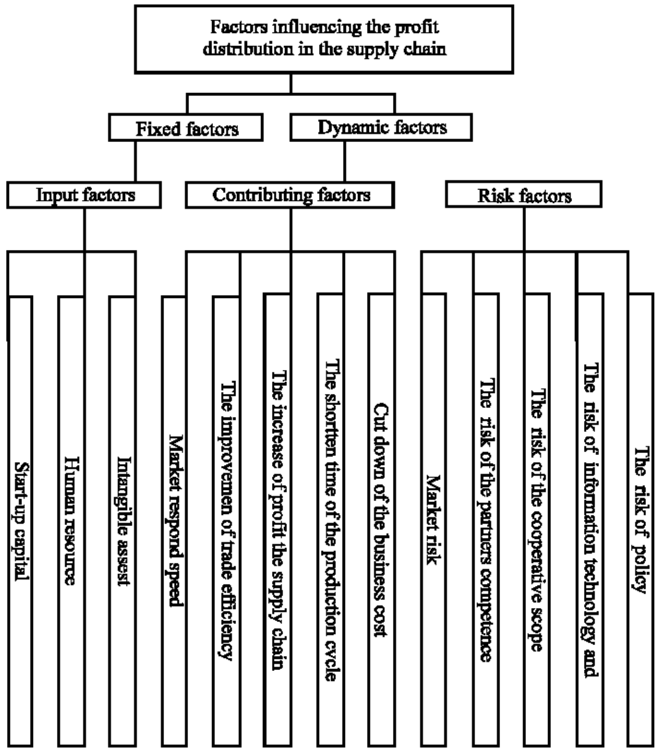

Fig. 1: Influential factors of profit distribution in the supply chain system

In practice, the risk factors, contribution level as well as the invest capital that each joint enterprise undertake should be considered in the centralized decisions of the supply chain. As it is supposed above that based on the Shapely value method, the profit distribution of the enterprise i is $\phi_i(v)$. According to the fact, the overall factors which influence the profit allocation should be taken into a comprehensive consideration. Then, suppose the profit that the enterprise real get is $\phi^*_i(v)$, the real risk coefficient is R_i, i = 1, 2, ..., n, meanwhile:

$$\sum_{i=1}^{n} R_i = 1$$

Besides, the difference between R_i and $\bar{R}$ is $\Delta R_i = R_i - \bar{R} = R_i - 1/n$ and:

$$\sum_{i=1}^{n} \Delta R_i = 0$$

When $\Delta r_i > 0$, it indicates that the risk which the enterprise i undertake is higher than the average. Namely, the profit distribution should be higher and the counter part still has the same effect. In the same way, suppose the real input coefficient of the enterprise i is I_i and:

$$\sum_{i=1}^{n} \Delta R_i = 1$$

then the difference between I_i and $\bar{I}$ is $\Delta I_i = I_i - \bar{I} = I_i - 1/n$. Besides,

$$\sum_{i=1}^{n} \Delta I_i = 0$$

When $\Delta I_i > 0$, it indicates that the invest capital of the corporation i is higher than the average in the supply chain. In respond, more profit should be distributed and the counter part still works as well. Additionally, suppose the contributing coefficient of the enterprise i to the alliance is C_i, then a equation can be got:

$$\sum_{i=1}^{n} C_i = 1$$

namely, the difference between C_i and $\bar{C}$ is $\Delta C_i = C_i - \bar{C} = C_i - 1/n$ and

$$\sum_{i=1}^{n} \Delta C_i = 0$$

If $\Delta C_i > 0$, it implies the contribution that the enterprise i makes for the supply chain is higher than the average and more interest should be paid. What's more, the opposite situation still works.

Then, the weight-vector $\omega = (\omega_1, \omega_2, \omega_3)$ of the risk factors, input factors and contributing factors could be calculated. Meanwhile $\omega_1+\omega_2+\omega_3 = 1$, so the overall modified factors of the enterprise i can be evaluated:

$$\Delta\rho_i = (\omega_1, \omega_2, \omega_3)^T \cdot (\Delta R_i, \Delta I_i, \Delta C_i) = \omega_1 \times \Delta R_i + \omega_2 \times \Delta I_i + \omega_3 \times \Delta C_i \quad (14)$$

Therefore, the modified profit value of the corporation x_i is $\Delta\varphi(i) = v(N)\times\Delta\rho_i$, in addition, the real interest value of the enterprise could be calculated based on the mentioned above:

$$\phi_i^*(v) = \phi_i(v) + \Delta\phi(i)$$

From the demonstration above, the modified sum of the assigned value is still equal to the overall income, therefore the modified results is reasonable.

The demonstration of the complex factor's modification is as follows:

$$\begin{aligned}
\sum_{i=1}^{n}\phi_i(v) &= \sum_{i=1}^{n}\left[\phi_i(v)+\Delta\phi(i)\right] \\
&= \sum_{i=1}^{n}\left[\phi_i(v)+v(N)\times\Delta Z_i\right] \\
&= \sum_{i=1}^{n}\phi_i(v)+v(N)\times\sum_{i=1}^{n}\Delta Z_i \\
&= \sum_{i=1}^{n}\phi_i(v)+v(N)\times\sum_{i=1}^{n}(\omega_1\times\Delta R_i+\omega_2\times\Delta I_i+\omega_3\times\Delta C_i) \\
&= \sum_{i=1}^{n}\phi_i(v)+v(N)\times\left[\omega_1\times\sum_{i=1}^{n}\Delta R_i+\omega_2\times\sum_{i=1}^{n}\Delta I_i+\omega_3\times\sum_{i=1}^{n}\Delta C_i\right] \\
&= \sum_{i=1}^{n}\phi_i(v) = v(N)
\end{aligned} \quad (15)$$

From the demonstration above, the modified sum of the assigned value is still equal to the overall income. Accordingly, the modified results $\varphi^*_i(v)$ are reasonable.

Therefore, the modified profit distribution value of the enterprise i is:

$$\phi_i^*(v) = \phi_i(v) + \Delta\phi(i) = \sum_{S \in S_i} \frac{(n-|S|)!(|S|-1)!}{n!}[v(S) - v(S \setminus \{i\})] + v(N)\times\Delta\rho \quad (16)$$

According to $\varphi_i^*(v)$, the modified profit distribution value of each enterprise in the supply chain can be figured out. Thus, the allocated results can be more reasonable, scientific and fair and the joint enterprises could be encouraged more to conduct an efficient operation for the coalition in the long run. In return, the conduct of the centralized decision could be more widely and effectively.

CONCLUSION

The only reason that each joint entity choose to cooperate is that every participant can attain more profit than their alone. However, the key point which the supply chain face is that how to distribute the profit reasonably, which relate to the stable development of the whole supply chain. It is obvious that the membership entities of the supply chain are relatively independent individuals in profit and decisions. Aiming at maximize their own profit, each entity is not totally rational in decision making. So the preference and the decision principles is ranging from time to time.

The Shapely value method of cooperative game theory (Giannoccaro and Pontrandolfo, 2004) is utilized for the primary distribution of the profit in the supply chain system, accordingly, the drawback of this pattern is taken into consideration. Combined with the differences of the real cost input, the undertaken risk and the contribution, the joint entities in the supply chain should adjust the profit distribution value for each side. Therefore, the Shapely value is modified accordingly, in order to distribute profit of the supply chain system among the joint enterprises more reasonably. As for how to distribute the profit of the supply chain under the centralized decision more reasonably, the profit distribution strategy model of the supply chain based on cooperative game theory is established efficiently. Moreover, the Shapely value of the profit distribution is given. Besides that, based on the real situation, the influential factors of the profit distribution of the joint entities in the supply chain are founded. Thus, the factors such as input, risk and contribution are brought about and integrated. Modify the Shapely value of the profit distribution and redistribute the interest in the supply chain, additionally; the problem of the profit distribution can be solved more effectively and reasonably. Thus, the profit can be maximized in the whole supply chain as well as in the joint entities. Therefore, the operation of the supply chain can be promoted and maintained efficiently and stably.

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