Profit allocation in collaborative product minor updates
supply chain enterprises based on improved shapely value

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Received 14 February 2016

Abstract
Because every member of the product minor updates supply chain enterprises had different position, different product minor updates resources and different level of risk, and they had different bargaining power during the profit allocation. In order to eliminate the profit conflict and imbalance of the profit allocation among partners, the improved shapely value model was studied. On the analyses of the principles of the profit allocation, we put forward four key factors affecting profit allocation about collaborative product minor updates in the supply chain and established the modified shapely model. Finally, we used numerical example to show the practicability and feasibility of the improved shapely value model.

Key words: Supply chain, Collaborative product minor updates, Profit allocation, Improved shapely value

1. Introduction

Collaborative product minor updates in the supply chain can make the member enterprises to obtain the complementary advantages of resources and spread minor updates risk, which is considered to be an effective product minor updates model. However, due to the complexity of the member enterprises in the supply chain, such as different position, different invested resources and different levels of risk, each member of the enterprises has the different bargaining power during the profit allocation. The irrational profit allocation can do harm to the target of collaborative product minor updates, leading to be inefficiency. Therefore, it is important for the collaborative product minor updates in the supply chain to allocate and coordinate profit after fully considering the characteristics of collaborative product minor updates.

Nowadays, a large number of scholars studied the profit allocation among the supply chain, mainly from three aspects. The first one is from the product transfer pricing, we can coordinate the profit allocation by determining the transaction price in the supply chain in order to achieve the best overall goals. For example, Giannoccaro et al.(2004) analyzed the product pricing decision process among the manufacturers, distributors and sellers, and proposed profit sharing contract in the supply chain among the three stages. He thought that the profit of supply chain could be improved through optimizing contract, but he did not give us the further analysis of the profit allocation among the enterprises; Fengyi Ai(2004) analysed the cooperative model of the upstream and downstream investment according to the two layer structure made up by a downstream monopolistic firm and many oligopolistic firms on the upstream, through the backward induction of product transfer pricing, she put forward the mechanism of practical profit allocation; Chauhan(2005) analysed the profit allocation model of the manufacturers, retailers and the wholesalers, he thought that the profit should be allocated in accordance with their risk and their investment. The second is the method of game theory, we should reach reasonable profit allocation in the satisfactory way through the establishment of mathematical model, and finally realize the inspiration for the whole supply chain. For example, Coach(2005) believed that if the decision behaviors of profit allocation among supply chain enterprises constituted a Nash equilibrium, any enterprise would not be willing to deviate from this equilibrium, then we could coordinate the profit allocation of supply chain; Huiping Pan etc.(2005) analysed the impact how the proportion of profit allocation affected the profits of manufacturers.
and retailers. He put forward the method of four-six into profit formula based on cooperative preference; Weihong Li et al. (2012) designed the profit coordinating mechanism of the up-and-down chain of enterprises according to the model of NASH bargaining based on satisfaction, it proved by the example that the mechanism of NASH bargaining could well coordinate the interests of all partners; Guilei Zhang (2006) proposed that the dominant enterprise could get the surplus profit through controlling the subordinate enterprises, while the subordinate enterprises could only get the retained profit; Wang Li (2010) established the cooperative profit game model of the principal-subordinate three-stage supply chain of downstream enterprises, got the solution with the method of STACKELBERG game, analysed the mechanism of profit allocation of the downstream enterprises in the supply chain quantitatively, and clarified the relationship between structural allocation and operational allocation of cooperative profit. The third is that we can take the problem of profit allocation in supply chain as the profit allocation of cooperative strategy for many people and we can distribute interests by using the method of shapely value according to the degree of importance in the process of profit creation in the supply chain. According to the research of the characteristics of running mechanism of supply chain, Shihua Ma (2006) solved the problem of profit allocation among the supply chain in enterprises by using the method of shapely value. Considering the importance of the enterprise product innovation, Shihua Ma adjusted the profit allocation share of the enterprises; Bahinipati (2009) established the frame of profit allocation according to the characteristics of semiconductor industry in the supply chain and he established the stability plan of the profit allocation with the method of shapely value; By using the method of SHAPLEY value, Wei Zhang (2008) discussed the problem of the three party collaborative product innovation profit allocation, that is suppliers, manufacturers and sellers, based on the process of non-collaborative, two-part collaborative and three-part collaborative.

The profit allocation ways of the enterprises in supply chain above have their pros and cons. Product transfer pricing method directly realizes the profit allocation between adjacent supply chain enterprises through product transfer price. This method is easily accepted by enterprises but there are so many factors affecting the pricing. And it method only focuses local interests not the whole profit of the supply chain. Game theory assumes that enterprises in supply chain focus on the whole profit and select the cooperative strategy while the method does not consider whether the dominating enterprise is good to the whole supply chain or not. And the calculation of these two methods is both complicated. Shapely value avoids average distribution, considers the importance of profit producing in different enterprises in supply chain and the calculation is convenient. But this method has not considered the risk ratio, additional contribution degree and other bargaining power factors on the final profit distribution. Although there is little literature considering the modified influence factors on the distribution, most of them think the factors determining the correction factor is single and the subjectivity is too strong.

Considering the above three methods of profit allocation in the supply chain enterprises, combined with the basic characteristics of collaboration product minor updates, on the analyses of the principles of the profit allocation, we put forward four key factors affecting profit allocation about collaborative product minor updates in the supply chain and establish the model of modified shapely collaborative product minor updates in the supply chain. Through the coordination of the profit allocation, this method achieves the optimal Pareto significance of the enterprises in supply chain.

2. The influencing factors of the profit allocation of the collaboration product minor updates in the supply chain

2.1 The principles of the profit allocation of the collaborative product minor updates in Supply chain

Enterprise members should reach an agreement for the allocation plan before the implement of the collaborative product minor updates in the supply chain. Due to the different enterprise status and information asymmetry, the enterprises should follow the principles of profit allocation to avoid the asymmetry of allocation plan about pay and profit. The basic principles of the profit allocation in supply chain are as follows:

1) The principle of mutual reciprocity and mutual profit

The main reason for the collaboration product minor updates in supply chain strategic partnership is that enterprises hope to achieve the integration of the resources and bring excess profits. In the end, all the enterprises achieve win-win. Profit allocation plan should not damage enterprises’ deserved profits and guarantee that all the enterprises can benefit from the collaboration. That is, if the supply chain is composed of M members, for any combination S of M members, the profit \( V(s) \), should meet \( v(\emptyset) = 0 \); \( v(s_1 \cup s_2) \geq v(s_1) + v(s_2); \ s_1 \cap s_2 = \emptyset. \)
(2) The principle of risk compensation

The member enterprises of collaborative product minor updates in supply chain are responsible for minor updates in different links, which are different in the input ratio of the resource, importance and risk sharing. The plan of the profit allocation should not only consider the product minor updates resources investment but also the risk ratio during the product minor updates of the enterprises members. If the member i take more risks than member j, the member i will get more profit than member j, that is: if $R_i > R_j$ then $v_i > v_j$.

(3) The principle of risk and profit

The process of collaborative product minor updates in supply chain is also a process to integrate and optimize for minor updates resources (including technology, equipment, funds, information and human resources), the investment proportion and the importance of enterprises determine their expectations for profit allocation of the product minor updates. Generally speaking, the more investment product minor updates resources, the more expected profit. If the enterprise i input more product minor updates resource than enterprise j, then the enterprise i will have more profits than enterprise j, that is: if $C_i > C_j$, then $v_i > v_j$.

(4) The principle of equity and efficiency

To ensure their cooperation and efforts, the collaborative product minor updates in supply chain needs enterprises to establish mutual trust and incentive mechanism among enterprises. Equitable profit allocation of the product minor updates is good to the cooperation, and avoids the conflict. But as a result of different part of the supply chain members making different contribution to product minor updates, different minor updates ability and utilization, it will affect the entire profit of the collaborative product minor updates in supply chain if we overemphasize on the fair. Therefore, we should insist on the principle of equity and efficiency on the profit allocation.

2.2 The factors of collaborative product minor updates in supply chain about profit allocation

Based on the analysis of basic principle of profit allocation about collaborative product minor updates in supply chain, this paper, combined with the basic characteristics of collaborative product minor updates process, put forward the factors that affecting the profit allocation.

(1) The contribution rate of the input resources of the product minor updates

Collaborative product minor updates in supply chain emphasize that member enterprises are reconstructed based on the whole target of the product minor updates. In the process of collaborative product minor updates in the supply chain, the member enterprises will put into the corresponding technology, talents, capital, knowledge and equipment, which are needed in the product minor updates. The contribution rate of the members of the enterprise to the whole supply chain is the main factor that affects the distribution of the cooperative product minor updates. According to the principle of risk and profit, the proportion of the contribution rate of the member enterprises is increasing with the proportion of income. Therefore, under the influence of the single factor of the product minor updates resource, the member enterprises in supply chain demand income increases with the increase of the contribution rate of the product minor updates resource.

(2) The coefficient of the risk sharing

Since product minor updates comes with many uncertain factors and risks, one of the advantages of the collaborative product minor updates in supply chain is to diversity risk, and relieves the pressure of the risk for single enterprise. The member enterprises in supply chain can cooperate through product minor updates resources complementary advantages. Each member enterprise can take the different product minor updates tasks based on their own advantages, at the same time; share the product minor updates risk in different degree. According to the principle of risk compensation, the higher risk, the greater profits. The first condition that can make the member enterprise to start the stable cooperation with the overall goal is that each party gets the corresponding benefit adapting to the risk. Therefore, the coefficient of risk sharing becomes the important basis for getting more allocation profit of the member enterprises in supply chain.

(3) The execution of the product minor updates task

Before we carry out the collaboration product minor updates in supply chain, each enterprise will carry on the division of the product minor updates tasks according to their advantages, and then form the contract. The execution of the product minor updates task can reflect the degree of efforts of the member enterprises in supply chain. Collaboration product minor updates in supply chain are based on the cooperation of enterprises, and each enterprise undertakes
different tasks in different process of the product minor updates. For their own autonomous interests, the member enterprises may appear to damage the overall goal of the product minor updates in the process. The execution level of product minor updates task measures the efforts degree of the member enterprises in supply chain in the process of collaborative product minor updates. Taking the execution of product minor updates task as the factor, it can avoid the negative behavior of the member enterprises, and maximize the profits in supply chain.

(4) The degree of additional contribution

The process of collaborative product minor updates in supply chain is full of uncertainties, so there will be unexpected emergency. In order to respond to the emergencies quickly, we will require some member enterprise in supply chain to take the additional tasks temporarily. For example, the new changes of the product technology, the improvement of product quality requirements, and these emergencies necessarily make the member enterprises to take extra cost in the product minor updates. The additional contribution should also be incorporated into the profit allocation of the product minor updates for encouraging the member enterprises to make more contribution to the overall goal for the collaborative product minor updates, and undertake the additional tasks actively.

3. The profit allocation model of improved shapely value of collaborative product minor updates in supply chain

3.1 The principle of shapely value model

The model of shapely value is a mathematical method to solve the cooperative problem in N persons. When a group of people engaged in an economic activity, they may form some cooperative subsets; each subset may gain some profits in the cooperation. The increase in the number of people will not lead to a decrease in revenue, while they can make the greatest profit; the model of shapely value is the plan to allocate the greatest profit. Hypothesis the set \( N = \{1, 2, 3, \ldots, n\} \), any subset \( S \) of \( N \) has a corresponding real-valued function \( V(s) \) and we called \( (N, V) \) for cooperative countermeasure of \( n \) persons, \( V(s) \) is defined the characteristic function on the \( N \). The model of shapely value meets the following axiom.

(1) The overall rationality.

The sum of profits of all the people is equal to the maximum of the value of \( n \) persons. That is:

\[
\sum_{i \in N} \phi(V) = V(N)
\]

(2) The symmetry.

If any two members in the \( N \) have the same marginal contribution to the subset \( S \), then they are symmetrical and they have the same distribution right in profit allocation. That is:

\[
\phi(V) = \phi(U)
\]

(3) The additivity.

The relation in shapely value of different countermeasures should be consistent with the relation in characteristic function. If \( U, V \) is arbitrary two countermeasures’ characteristic functions of the set \( N \), while \( U + V \) means the characteristic function when the two countermeasures are put together, it should be:

\[
\phi(U + V) = \phi(U) + \phi(V)
\]

After meeting the three axioms, according to the theorem of shapely value, if

\[
V(\emptyset) = 0; V(I \cup \{i\}) \geq V(I) + V(\{i\}), I \cap \{i\} = \emptyset, \text{a subset of } N \text{, hypothesis } \phi \text{ means the profit of enterprises } i. \text{ The calculation formula of shapely value is: }
\]

\[
\phi(V) = \sum_{|S|} \frac{(|S|-1)!(n-|S|)!}{n!} [V(S) - V(S - \{i\})]
\]

\( |S| \) means scale of the enterprise in the cooperative game; \( V(S) - V(S - \{i\}) \) means the cooperative profit of the players I. That is the cooperative marginal contribution of the enterprises I:

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

means the probability that enterprise participates in S.
In this paper, we take the three level supply chain composed of a core manufacturer, suppliers and sellers as the subjects, during the process of calculation of profit allocation of the collaborative product minor updates in supply chain, \( i = 1,2,3 \) respectively mean the core manufacturers, suppliers and sellers in collaborative product minor updates; \( n \) means the number in the process of cooperation, that is \( n=3 \); \( S \) means any cooperation subset of core manufacturers, suppliers and sellers, \( \phi_i(V) \) \( \phi_i(V) \) \( \phi_i(V) \) mean the allocated profits of the core manufacturers, suppliers and sellers before correction respectively.

3.2 The modification of the shapely value

The model of shapely value is based on the marginal profit. According to the members’ marginal contribution of the cooperative strategy, the distribution of income is determined. Symmetry is an important assumption of the method of shapely value, but the assumption ignores other factors except the marginal contribution. Symmetry assumes that the impact of the income distribution is equal (as \( 1/n \)).which is difficult to reflect the standards of fairness of the profit allocation. The process of collaborative product minor updates in supply chain is a process of integrating and optimizing product minor updates resources, which takes the product as the center. In accordance with their advantage, each enterprise plays different roles in the process of collaborative product minor updates. The member enterprise will have the difference in the product minor updates task, the rate of contribution, risk of product minor updates and the additional contribution in the process of the product minor updates, which form the enterprise’ bargaining power in the profit allocation of the product minor updates. Therefore, in the profit allocation of the collaborative product minor updates in supply chain, we must modify the shapely value based on the above factors.

Based on the shapely value, considering the factors of profit allocation about collaborative product minor updates, we establish the modified set of profit allocation \( \{ J_{m} \} \) = \( \{ L, 1,2,\ldots,n \} \), the measured value of correction factors \( j \) of the member enterprise \( i \) in the set \( N \) is \( a_{ij} \) \( (i=1,2,\ldots;n; j=1,2,\ldots,m) \). As is shown in table 1:

| Manufacture | Supplier | Seller |
|-------------|----------|--------|
| the contribution rate of input resources of the product minor updates | the coefficient of the risk sharing | the execution of product minor updates task | the degree of additional contribution |
| \( a_{11} \) | \( a_{12} \) | \( a_{13} \) | \( a_{14} \) |
| \( a_{21} \) | \( a_{22} \) | \( a_{23} \) | \( a_{24} \) |
| \( a_{31} \) | \( a_{32} \) | \( a_{33} \) | \( a_{34} \) |

Table 1  Modified analysis factor.

Then the modified matrix \( A = (a_{ij})_{\text{new}} \) is:

\[
A = (a_{ij})_{\text{new}} = \begin{bmatrix}
  a_{11} & a_{12} & a_{13} & a_{14} \\
  a_{21} & a_{22} & a_{23} & a_{24} \\
  a_{31} & a_{32} & a_{33} & a_{34}
\end{bmatrix}
\]

(2)

Because the modified factors have the different dimensions, units and orders of magnitude, we need to normalize the matrix in order to eliminate the immeasurability of the non-public degree and then get the standardized matrix of profit allocation \( B = (b_{ij})_{\text{new}} \).Because the four modified factors of profit collaborative product minor updates in supply chains are positive indicators, the following method can be adopted for the process

\[
b_{ij} = \frac{a_{ij} - \min_j a_{ij}}{\max_i a_{ij} - \min_j a_{ij}}
\]

(3)

First determine the weight of each factor on the profit allocation of the collaborative product minor updates in supply chain \( \lambda = [\lambda_1 \lambda_2 \lambda_3 \lambda_4] \), and then calculate the comprehensive coefficient of the factors on the profit allocation .The calculation formula is as follow:
\[
[D_1, D_2, D_3]^T = B \times \lambda
\]  

(4)

D1, D2, D3, respectively indicates the degree of the impact of suppliers, manufacturers and sellers on the distribution of cooperative product minor updates. Then after correction, the shapely value of suppliers, manufacturers and sellers in profit allocation of collaborative product minor updates is:

\[
\phi'_V = \phi_V + (D_i - \frac{1}{n}) \times V(N)
\]  

(5)

3.3. Method for determining the parameters of the model

(1) The contribution rate of the input resources of the product minor updates

Any minor updates product is the common result of several kinds of product minor updates resource elements. Every kind of resources that take part in product minor updates makes the contribution to the product minor updates. Therefore, it should be paid from the profit of the product minor updates. The product minor updates resources not only refer to the input of innovative technology, capital and information, but also include the equipments, the places and the human cost during the process of the product minor updates. The supply chain enterprises should not use the actual cost as the basis during the profit allocation of product minor updates, while based on the actual rate of contribution in the whole supply chain of collaboration in product minor updates. We can take the following method to make sure the rate of contribution of product minor updates resources.

Assuming the member enterprises in supply chain invested m kinds of product minor updates resources respectively and m is the maximum number of the invested kind of product minor updates resources. \( P_{ij}(i=1,2,3; j=1,2,3...m) \) means the cost value that the member enterprise I of the supply chain invested the product minor updates resources j , and \( P_{ij} \geq 0 \).

Because each member enterprises of the supply chain undertake the different product minor updates tasks, some may invest less than m kinds of resources. At this moment, the cost of not invested resources for this member is \( P_{ij}=0 \). Because the member enterprises of the supply chain have different position in the process of product minor updates, the importance of resources to the collaborative product minor updates in supply chain will be a big difference. Assuming \( K_j \) means the value weight of the resources j and the value is proportional to the importance of the resources of the supply chain. Adjusting to the product minor updates resource value by using \( K_j \), then we will form the product minor updates resources value of this member enterprise. The calculation formula is as follow:

\[
PK = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ p_{31} & p_{32} & \cdots & p_{3m} \end{bmatrix} \times \begin{bmatrix} k_1 \\ k_2 \\ \vdots \\ k_m \end{bmatrix} = \begin{bmatrix} cv_1 \\ cv_2 \\ cv_3 \end{bmatrix}
\]

(6)

\( cv_1, cv_2, cv_3 \) mean the overall product minor updates resource value that the member enterprises of the supply chain have paid for respectively. \( a_{11}, a_{21}, a_{31} \) means the contribution rate of the product minor updates resources that the manufacturers, suppliers and sellers have invested ,that is :

\[
a_{11} = \frac{cv_1}{cv_1 + cv_2 + cv_3} ; \quad a_{21} = \frac{cv_2}{cv_1 + cv_2 + cv_3} ; \quad a_{31} = \frac{cv_3}{cv_1 + cv_2 + cv_3}
\]

(2) The coefficient of the risk sharing

The risk of collaborative product minor updates in supply chain exists in the whole process from the creative ideas to the sales promotion. In the different stages of the product minor updates, suppliers, manufacturers and sellers take the different risk on the kind and proportion. It is not much enough to distinguish the proportion of the risk in the enterprises of the collaborative product minor updates only from the characteristics of the product minor updates, the subject of the product minor updates or the characteristics of risk. It cannot reflect the rule of risk changes in the process of the product minor updates. In this paper, we can make sure the coefficient of risk sharing in the process of collaborative product minor updates in the supply chain based on the risk analytic matrix of the product minor updates and the fuzzy comprehensive evaluation method.

Based on the research and analysis to the risk of collaborative product minor updates in supply chain by the
Table 2  Analytic matrix of collaborative product minor updates risk.

| $i \setminus j$ | Technology investment risk | Production investment risk | Funding risk | The labor risk | Cooperative credit risk | Market promotion risk |
|-----------------|---------------------------|---------------------------|-------------|---------------|------------------------|----------------------|
| Product minor updates ideas | $m_{11}, s_{11}, r_{11}$ | $m_{12}, s_{12}, r_{12}$ | $m_{13}, s_{13}, r_{13}$ | $m_{14}, s_{14}, r_{14}$ | $m_{15}, s_{15}, r_{15}$ | $m_{16}, s_{16}, r_{16}$ |
| Survey and evaluation r&d | $m_{21}, s_{21}, r_{21}$ | $m_{22}, s_{22}, r_{22}$ | $m_{23}, s_{23}, r_{23}$ | $m_{24}, s_{24}, r_{24}$ | $m_{25}, s_{25}, r_{25}$ | $m_{26}, s_{26}, r_{26}$ |
| Product test production | $m_{31}, s_{31}, r_{31}$ | $m_{32}, s_{32}, r_{32}$ | $m_{33}, s_{33}, r_{33}$ | $m_{34}, s_{34}, r_{34}$ | $m_{35}, s_{35}, r_{35}$ | $m_{36}, s_{36}, r_{36}$ |
| Sales promotion | $m_{41}, s_{41}, r_{41}$ | $m_{42}, s_{42}, r_{42}$ | $m_{43}, s_{43}, r_{43}$ | $m_{44}, s_{44}, r_{44}$ | $m_{45}, s_{45}, r_{45}$ | $m_{46}, s_{46}, r_{46}$ |

$i$ represents the different stages of the product minor updates, $j$ means the kind of the risk, $m_{ij}$, $s_{ij}$, $r_{ij}$ mean the different kinds of risk proportion that the manufacturers, suppliers and sellers take in different stages of the product minor updates. We can determine the value of $m_{ij}$, $s_{ij}$, $r_{ij}$ by using the fuzzy comprehensive evaluation method. Assuming $V^k\_y = (L_y^k, M_y^k, U_y^k)$ represents the triangular fuzzy number that the product minor updates expert $k$ gives the evaluation of the manufacturers on the risk $j$ of the stage $i$ about the collaborative product minor updates. Considering the evaluation of all the experts, we can get the average of fuzzy comprehensive evaluation $V_y = (L_y, M_y, U_y)$ . After removing fuzziness, we can get $m_y = [(U_y - L_y) + (M_y - L_y)] / 3 + L_y$. In the same way, we can get $s_y, r_y = 1 - m_y - s_y$. We can give the weight $\theta$, $\theta = (\theta_1, \theta_2, \theta_3, \theta_4, \theta_5)$ according to the distribution of risk in the process of the product minor updates and give the weight $\omega = (\omega_1, \omega_2, \omega_3, \omega_4, \omega_5)$ according to the types of risks of collaborative product minor updates influence. The coefficient of the risk sharing of the manufacturers, suppliers and sellers about collaborative product minor updates in supply chain respectively is:

$$a_{12} = \sum_{j}^{} \theta \sum_{j}^{} \omega m_{ij} ; \quad a_{22} = \sum_{j}^{} \theta \sum_{j}^{} \omega s_{ij} ; \quad a_{32} = \sum_{j}^{} \theta \sum_{j}^{} \omega r_{ij} , \quad \text{and} \quad a_{12} + a_{22} + a_{32} = 1$$

(3) The execution of product minor updates task

Collaborative product minor updates in supply chain take the maximum profit as the ultimate goal. The enterprises undertake the corresponding task according to their own advantage of the product minor updates. The characteristics of the distributed product develop process exert complementary advantages, but there may also lead to the contradiction between individual goal and overall goal of the member enterprise in supply chain. The same member enterprise in supply chain may participate in different items in supply chain and show the different enthusiasm and effort in the process of the collaborative product minor updates in supply chain. According to the execution of product minor updates task, to measure the efforts of the member enterprises, we can not only coordinate the contradiction between the individual goals and overall objectives, but also stimulate the member enterprises to make the greatest efforts for the collaborative product minor updates.

In order to determine the execution of collaborative product minor updates task in supply chain, we can make sure the product minor updates tasks, time schedule and quality objectives in advance according to the task allocation cooperation contract of the member enterprises in supply chain. Next, we will measure and evaluate the actual condition with the task objectives, time schedule and quality objectives; At last, with then using the method of comprehensive evaluation, we will get the value of the execution of product minor updates task of the collaborative product minor updates in supply chain $a_{13}, a_{23}, a_{33}$.

(4) The degree of additional contribution

In the process of collaborative product minor updates in supply chain, in order to adapt the changes of the
environment, the enterprises in supply chain need to pay extra efforts outside the cooperation contract sometimes and undertake additional tasks temporarily, which will pay extra cost. We should consider this situation when we carry out the allocation of the collaborative product minor updates. To ensure the degree of additional contribution of the collaborative product minor updates in supply chain, we should firstly ensure the situation that will produce negative benefit to the maximum target of the profit in the process of collaborative product minor updates in supply chain. Secondly, to make sure the resources cost of technology, human and capital which is used to solve the sudden problems of the member enterprise in supply chain. Finally, we can calculate value of the degree of additional contribution for every member enterprise. Assuming the extra cost in the process of collaborative product minor updates of the manufacturers, suppliers and sellers is respectively $C_m$, $C_s$, $C_r$, then the value of the degree of additional contribution for every member is as follow:

$$a_{41} = \frac{C_s}{C_s + C_m + C_r}; \quad a_{42} = \frac{C_m}{C_s + C_m + C_r}; \quad a_{43} = \frac{C_r}{C_s + C_m + C_r}$$

4. The research of Mathematics
4.1 To ensure the profit of shapely value

Taking an example of the product minor updates of the variable speed night vision spherical cameras produced in a technology Electronics Co., Ltd of Tianjin, the company, acting as the core manufacturer, combines a supplier and a seller to form the collaborative product innovated supply chain. Through the evaluation of the product minor updates project, total profit of three party on collaborative product minor updates is 12 million Yuan, the collaborative product minor updates with its suppliers can benefit 7.2 million Yuan, the collaborative product minor updates with its sellers contributes 8.5 million Yuan, the collaborated product minor updates between suppliers and sellers can benefit 5.5 million Yuan. If the company makes product minor updates independently, the company will benefit 4.5 million Yuan, the suppliers will benefit 5.5 suppliers, and the sellers will benefit 3 million Yuan. Using the method above, we can get parameter values of the model, as is shown in table 3.

| Profit of collaborative part (million) | Modified matrix |
|--------------------------------------|-----------------|
|                                      | The contribution rate of the input product minor updates resources | The coefficient of the risk sharing | the execution of product minor updates task | the degree of additional contribution |
| Manufacturers (main)                  | $a_{41} = \frac{C_s}{C_s + C_m + C_r}$ | $a_{42} = \frac{C_m}{C_s + C_m + C_r}$ | $a_{43} = \frac{C_r}{C_s + C_m + C_r}$ |
| Supplier                             | 0.37            | 0.44            | 0.33            | 0.40        |
| Sellers                              | 0.35            | 0.23            | 0.33            | 0.36        |
| Seller                               | 0.28            | 0.33            | 0.33            | 0.24        |

The total profit of collaborative product minor updates among three parties is 1200

Based on the data of table 3, According to the method of shapely value (1), we can get the profit allocation of main manufacturer, as is shown in table 4:
When $s=\{1\}$, that means the manufacture will benefit 4.5 million Yuan, $v(s)$=450.

Then $v(s)=v(\emptyset)$=0;

$v(s)-v(s|1)=450$;

$|s|=1$;

$[((|s|-1)!/(n-|s|)!)/n!]/n!$=1/3

Similarly, when $s=\{1, 2\}$, $[((|s|-1)!/(n-|s|)!)/n!]$ $v(s)-v(s|1)=520\times1/6=86.7$

when $s=\{1, 3\}$, $[((|s|-1)!/(n-|s|)!)/n!]$ $v(s)-v(s|1)=550\times1/6=91.7$

When $s=\{1, 2, 3\}$, $[(|s|-1)!/(n-|s|)!/n!]$$v(s)-v(s|1)=650\times1/3=216.7$

According to the formula (1), when we add the four numbers together of the last line of table 4, 150+86.7+91.7+216.7=545.1, we round to 545, that means $\phi_1=545$.

Similarly, to get the result of $\phi_2$, we should calculate the numbers when $S=2$. The specific steps are shown in the following table (table 5). when we add the four numbers together of the last line of table 5, 66.7+45+41.7+116.7=270.1, we rounded to 270, that means $\phi_2=270$.

To get the result of $\phi_3$, we should calculate the numbers when $S=3$. The specific steps are shown in the following table (table 6). When we add the four numbers together of the last line of table 6, 100+66.7+58.3+160=385, that means $\phi_3=385$. 

Table 4  Calculation of shapely value for the main manufacturer

| $s$       | 1 | 1∪2 | 1∪3 | 1∪2∪3 |
|-----------|---|-----|-----|-------|
| $v(s)$    | 450 | 720 | 850 | 1200  |
| $v(s|1)$  | 0  | 200 | 300 | 550   |
| $v(s)-v(s|1)$ | 450 | 520 | 550 | 650   |
| $|s|$      | 1  | 2   | 2   | 3     |
| $[((|s|-1)!/(n-|s|)!)/n!]$ | 1/3 | 1/6 | 1/6 | 1/3   |

Table 5  Calculation of shapely value for the supplier

| $s$       | 2 | 1∪2 | 2∪3 |
|-----------|---|-----|-----|
| $v(s)$    | 200 | 720 | 550 | 1200 |
| $v(1∪2∪3\backslash s|1)$ | 0  | 450 | 300 | 850  |
| $v(s)-v(s|2)$ | 200 | 270 | 250 | 350  |
| $|s|$      | 1  | 2   | 2   | 3     |
| $[((|s|-1)!/(n-|s|)!)/n!]$ | 1/3 | 1/6 | 1/6 | 1/3   |

Table 6  Calculation of shapely value for the seller

| $s$       | 3 | 1∪3 | 2∪3 | 1∪2∪3 |
|-----------|---|-----|-----|-------|
| $v(s)$    | 300 | 850 | 550 | 1200  |
| $v(s|3)$  | 0  | 450 | 200 | 7200  |
| $v(s)-v(s|3)$ | 300 | 400 | 350 | 480   |
| $|s|$      | 1  | 2   | 2   | 3     |
| $[((|s|-1)!/(n-|s|)!)/n!]$ | 1/3 | 1/6 | 1/6 | 1/3   |
After verification, the profit allocation plan of the collaborative product minor updates in supply chain meets rationality, symmetry and the additive.

4.2 Modified shapely value

The impact weight of each factor on the distribution of the collaborative product minor updates in supply chain with AHP (Analytic Hierarchy Process) method is \( \lambda = \begin{bmatrix} 0.28 & 0.60 & 0.07 & 0.05 \end{bmatrix}^T \). We invited the collaborative product minor updates managers and experts to compare two assignments, formed the contrast matrix, and finally calculated the weight of each influence factor. According to table 3 we can get the corrected matrix \( B \):

\[
B = (b_{ij})_{4 \times 4} = \begin{bmatrix}
0.37 & 0.44 & 0.33 & 0.40 \\
0.35 & 0.23 & 0.33 & 0.36 \\
0.28 & 0.33 & 0.33 & 0.24 \\
\end{bmatrix}
\]

According to (4), we can calculate the comprehensive influencing coefficient of collaborative product minor updates in supply chain:

\[
\begin{bmatrix} D_1 & D_2 & D_3 \end{bmatrix}^T = B \times \lambda = \begin{bmatrix}
0.37 & 0.44 & 0.33 & 0.40 \\
0.35 & 0.23 & 0.33 & 0.36 \\
0.28 & 0.33 & 0.33 & 0.24 \\
\end{bmatrix} \begin{bmatrix} 0.28 & 0.60 & 0.07 & 0.05 \end{bmatrix}^T = \begin{bmatrix} 0.41 \\
0.28 \\
0.31 \\
\end{bmatrix}
\]

It can be calculated from profit allocation of the modified shapely value of the main manufacturer, supplier and seller by (5):

\[
\phi'_1(V) = \phi_1(V) + (D_1 - \frac{1}{n}) \times V(N) = 545 + (0.41 - \frac{1}{3}) \times 1200 = 637
\]

\[
\phi'_2(V) = \phi_2(V) + (D_2 - \frac{1}{n}) \times V(N) = 270 + (0.28 - \frac{1}{3}) \times 1200 = 206
\]

\[
\phi'_3(V) = \phi_3(V) + (D_3 - \frac{1}{n}) \times V(N) = 385 + (0.31 - \frac{1}{3}) \times 1200 = 357
\]

The profit allocation of the main manufacturer, supplier and seller still meets rationality after revision, meeting the condition of collaborative product minor updates of three parties. The revised result shows that, because the main manufacturer plays an important role in the contribution of the resources, risk sharing and the additional tasks, it has stronger bargaining power in collaborative product minor updates; the modified shapely value is higher than the basic allocation of the profit. While supplier and seller are in the vulnerable bargaining position, the modified shapely value is below the basic allocation of the profit. The modified shapely value can better reflect the situation of the collaborative product minor updates in the supply chain of three parties, which means the main manufacturer plays a critical role in the process from the minor updates idea to the sales promotion, and the revised scheme is more reasonable and fair.

5. Conclusion

This paper combined with the characteristics of collaborative product minor updates in supply chain, based on the principles of profit allocation about collaborative product minor updates in supply chain, comprehensively considering the impact of profit allocation about collaborative minor updates in supply chain, that is: the contribution rate of the input resources of the product minor updates, the coefficient of the risk sharing, the execution of product minor updates task and the degree of additional contribution. Then we established profit allocation model with revised shapely value about collaborative product minor updates in supply chain. By using this model, we could effectively coordinate the conflicts among enterprises in supply chain, which would make the profits of every member enterprise more fair and reasonable so as to make foundations for the management of collaborative product minor updates in supply chain.
6. Discussion

The model of collaborative product minor updates in supply chain provided the platform for the supply chain members to integrate resources and form of complementary advantages. Taking product minor updates as the goal to integrate resources, the members in supply chain would maximize the overall product minor updates target. For future research, the proposed model may be considered to the large-scale technological innovation in the supply chain and at that time, the coefficient of the risk sharing will be great changes with the members to participate in depth.

Acknowledgment

This work was supported by the Project of Tianjin Philosophy and Social Sciences [TJLJ16-002,TJZDWT1603, TJYYWT16-018,TJGL15-049], the Project of Think Tank Building Center in Tianjin Normal University [52WZ1502], and the Project of Tianjin Talent Development Fund.

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