Research on the Cooperative Game under Joint Distribution Based on Integrated Logistics Solution for Small and Medium-sized Electronic Commerce Enterprises

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ABSTRACT

In recent years, small and medium-sized e-commerce enterprises show the trend of rapid growth. However, separate enterprise distribution and self-build warehousing storage gradually highlight the shortcomings of high cost and low efficiency. Considering the features of small and medium-sized e-commerce enterprises, it is suitable to apply joint distribution combined with them. Joint distribution relates to the interests of the cooperative enterprises, which means reasonable cost allocation method and profit allocation mechanism are the key to promoting the normal operation of the joint distribution. This paper took the distribution enterprises which service for the small and medium-sized e-commerce enterprises as the background, put forward the joint distribution mode for small and medium-sized electronic commerce enterprises, established the multilateral game mode for joint distribution based on the related knowledge of game theory, and studied the cost allocation and profit distribution. This paper provides integrated logistics joint solution for small and medium-sized e-commerce enterprises.

INTRODUCTION

The commodity business and distribution of small and medium-sized e-commerce enterprises should be adapt to different regions, different time and different consumption demands, objectively, they also need modern logistics services to meet different varieties, small batch, and high frequency, as well as higher service level, reduces logistics costs. These must be done by logistics joint distribution.

The premise of multiple enterprises are willing to joint distribution is profits of joint distribution must be greater than the sum of all corporate profits brought by the separate distribution. Reasonable cost allocation and profit allocation mechanism is the key to promote the joint distribution operation properly. In this paper, a multilateral game mode for joint distribution for small and medium-sized e-commerce enterprises is established, and a reasonable allocation between cooperative enterprises is put forward.
JOINT DISTRIBUTION MODE FOR SMALL AND MEDIUM-SIZED E-COMMERCE ENTERPRISES

The Structure of the Joint Distribution Mode

(a) Small and medium-sized e-commerce enterprises: small and medium-sized e-commerce enterprise refers to the enterprise which has related trading platform with the customer, but do not have independent ability of logistics service, only do virtual marketing. Most of these enterprises needed a logistics provider which provides storage and distribution integrated logistics service to fulfill their business orders. They are the main service object of urban joint distribution mode.

(b) Warehousing enterprises: warehousing enterprise is the core part of the joint delivery, it is the center of network of a variety of logistics basic activities and functions combination.

(c) Express enterprises: express companies which take delivery of last kilometer and join terminal customers and warehousing logistics enterprises play an important role in joint distribution system.

The Operation Procedure of Joint Delivery

Logistics enterprises whose main business is warehousing adopt the network computer technology, modern hardware equipment, software system and the advanced management methods, putting goods together to the joint distribution center with the help of distribution logistics enterprises whose main business is delivery, then conducting storage, intelligent selection, path optimization, the implementation of the scheduling and monitoring, make sure goods can be given to all types of users in time.

The flow chart of joint distribution mode is below:

Figure 1. Joint distribution mode flow diagram.

Customer orders accepted by small and medium-sized e-commerce enterprises

Orders summary

Distribution and sorting

Delivery plan

Inventory management

Replenishment

Packing and weighing

Warehousing enterprises

Taking goods from warehouse

Delivery

Receiving the payments

Express enterprises
TABLE I. PROFIT OF THE TWO ENTERPRISES.

|       | non-cooperation | cooperation |
|-------|-----------------|-------------|
| X non-cooperation | \( P, P \) | \( S, T \) |
|       | \( T, S \)     | \( R, R \)  |

The Cooperative Game Model under Joint Delivery

Members in joint distribution can cooperate on the premise of information sharing which is based on the pursuit of common interests. Therefore, the essence of joint distribution is cooperative game; multiple enterprises make an alliance by signed joint distribution logistics cooperation agreement, then delivery goods together and split joint distribution of total costs and total benefits in the way accordance with relevant provisions of the agreement. Game model includes three elements: participants, strategy sets, and pay-off function.

(a) Participants: the participants of this model have three, the small and medium-sized e-commerce enterprise, the warehousing enterprise and express enterprise. In this model, the logistics enterprises are based on warehousing enterprises and express enterprises, so the actual participants can be regarded as two parties, small and medium-sized e-commerce enterprises \( X \) and logistic enterprises \( Y \).

(b) Strategy set: the strategy set of game model can be dividing into two categories, the cooperation mode and the mode of non-cooperation. In this case, cooperation mode refers to the participants carry out joint distribution; On the contrary, it is the non-cooperation mode.

(c) Pay off function: pay off function is the participants’ effectiveness from the game; it is a function of all participants’ strategy or action. The benefit of participants in this model is shown in the following table:

The former of the table refers the benefit of \( X \); the latter refers the benefit of \( Y \).

\( T \) refers temptation; \( R \) refers cooperation remuneration; \( P \) refers punishment; \( S \) refers cheated.

Regarding the process of game between \( X \) and \( Y \) as a repeated game process, and do four hypotheses to the behavior of two companies.

(a) Rational assumptions: assumes that all companies have completely rational behaviors;

(b) The economic rational hypothesis: assumes that all companies have rationality of pursuing vested interests;

(c) Information completely assumption: all companies not only know their interests after every action, also fully know each other's benefit and corresponding policy steps;

(d) Yields meet condition \( T > R > P > S \): the earning of two distribution enterprises after cooperation is more than the benefit of two companies don’t choose cooperation, namely \( R > P \); After cooperation, if any party take betrayal (non-cooperation), the betrayal party will take more gains than the party take cooperative behavior, because the betrayal party is able to obtain more benefits, and the party
which still take cooperative behavior will suffer losses, but the total revenue income is still higher than both parties don’t choose cooperation, namely \( T > R > S > P \).

**SOLVE ALGORITHM OF MODEL**

Nash negotiation method is proposed by Nash through using game theory analysis tool, it is a key role to solve the problem of cooperation countermeasure, it uses the axiomatic methods to get achieve rational results. Participants in the joint distribution can achieve negotiation under complete information sharing, and try to achieve reasonable interests among many members. This article will use Nash negotiation method to solve the problem of cost allocation among partners.

Shapley value method is a mathematical method used to solve the problem of multiple participants’ cooperation strategy. When the parties are engaged in a common economic activity, each kind of cooperation of multiple participants will receive certain benefits. When the activity is non-confrontational, the increase number of cooperation’s parties cannot reduce total benefits, all parties choose cooperation will bring the biggest benefits; Shapley value method is a scheme to distribute the maximum benefits. This article will use Shapley value method to solve the problem of distribution of benefits among partners.

**Nash Negotiation Algorithm**

Nash bargaining model provides an optimal allocation scheme.

The collection \( N = \{1, 2, 3, \ldots, n\} \) on behalf of cooperative enterprises which participated in joint distribution, \( C = \{c_1, c_2, c_3, \ldots, c_n\} \) on behalf of the cost of enterprises carry out distribution service alone, \( X = \{x_1, x_2, x_3, \ldots, x_n\} \) on behalf of each enterprise’s sharing cost. Through Nash bargaining theory; Nash product \( \prod_{i \in N} (c_i - x_i) \) is the product of maximizes cost savings of cooperative enterprises.

\( X \) can be solved by solving the nonlinear programming problem:

\[
\max \prod_{i \in N} (c_i - x_i) \tag{1}
\]

\[
s.t. \sum_{i \in N} x_i - C(N) = 0 \tag{2}
\]

\[
\Delta c < x_i < c_i \tag{3}
\]

Constraint condition \( \sum_{i \in N} x_i - C(N) = 0 \) shows collective principle, \( \Delta c < x_i < c_i \) shows the result of cost allocation has individual rationality, \( \Delta c_i \) represents the marginal cost, marginal cost can be expressed as \( \Delta c_i = C(N) - C(N - \{i\}) \), the cost allocation of a joint distribution alliance has an important principle to follow: the sharing cost of an individual enterprise is at least equal to the added value of total cost of joint distribution caused by this enterprise joins the joint distribution. It also called the marginal cost of the enterprise.
Shapley Value Method

\[ X = \{X_1, X_2, X_3, \ldots, X_n\} \] represents allocation strategy of cooperative game countermeasures, \( X_i \) represents member \( i \)'s income from the maximum benefits \( V(N) \). Shapley value method should meet the following three conditions:

(a) Effective conditions: if each subset \( S \) which has \( i \) cooperative enterprises meet conditions \( V(S - i) = V(S) \) and \( \sum X_i(V) = V(N) \), \( X_i(V) \) will be equal to 0. It means if enterprise makes no contribution to others in cooperation, it will not get profit from others, and the total income of all members participate in joint distribution are equal to the sum of total profit in this model.

(b) Symmetry conditions: \( \pi \) is the arbitrary arrangement of \( N = \{1, 2, 3, \ldots, n\} \), if \( \pi i \) is the corresponding of \( i \), and \( \pi S \) is the corresponding of \( S \) (\( S \subset N \)); \( V(\pi S) = \mu(S) \), \( X_{\pi i}(V) \) will be equal to \( X_i(\mu) \). It means each member's interests allocation has nothing to do with the mark in the model, namely position is symmetrical.

(c) Addictive conditions: if two characteristic functions \( \mu \) and \( V \) have the equation \( X_i(\mu + V) = X_i(\mu) + X_i(V) \) and enterprises participate in two cooperation at the same time, the total income should be the sum of two cooperation benefits, the value can be added.

Shapley value is determined by the characteristic function \( V \), denoted by \( X = \{X_1, X_2, X_3, \ldots, X_n\} \), the calculation formula of \( X_i \) is:

\[
X_i(V) = \sum_{S \in S_i} W(|S|)[V(S) - V(S - i)] \quad (i = 1, 2, 3 \ldots, n)
\]

(4)

\[
W(|S|) = \frac{(n - |S|)!(|S - i|)!}{n!}
\]

(5)

In type (5), \( |S| \) is the number of elements in the subset \( S \), \( W(|S|) \) is a weighting factor.

The calculation formula of Shapley value can be understood as a kind of probability calculation. Assuming that participants in the cooperation cooperate in a random sequence of order, the probability of each order is equal to \( \frac{1}{n!} \), if participant \( i \) reached cooperation \( S \) with participant \( |S| - 1 \), the participation enterprise \( i \)'s contribution to the cooperation will be \( V(S) - V(S - i) \), it is also called marginal contribution of the enterprise. The orders of \( S - i \) and \( N - S \) have \( (n - |S|)!(|S - i|)! \) species, the probability of each order is equal to \( \frac{(n - |S|)!(|S - i|)!}{n!} \), the Shapley value is the value of contribution expectation of enterprise \( i \).
CASE STUDY

Numerical Example Structure

Relying on project “City joint distribution system integration and application demonstration for small and medium-sized e-commerce enterprises” of Beijing science and technology commission and the data provided by a modern logistics warehousing company, costs are divided into fixed costs and operating costs, fixed costs refer to one-time investment costs and expenses on the prophase of launch; operating costs refer to the cooperative enterprise’s own operating costs. All kinds of costs are shown in the table below:

Cost Allocation of Joint Distribution Model

This mode involves three parties: e-commerce enterprise, logistics warehousing enterprise and express delivery company. They have different cooperation modes, so distribution costs are also different.

Regarding those enterprises as members involved in the cooperative game, regarding e-commerce enterprise as $A$, regarding logistics warehousing enterprise as $B$, regarding express delivery company as $C$, a collection of players as $N = \{A, B, C\}$, a subset $S = (\{A\}, \{B\}, \{C\}, \{A, B\}, \{A, C\}, \{B, C\}, \{A, B, C\})$, $S$ represents all the ways of cooperation.

When members operated independently, three parties for cost are shown in the table below:

![Table II. Cost Types (Million Yuan)]

| Cost types | Fix costs | Operating costs |
|------------|-----------|-----------------|
| e-commerce enterprises | 45 | 35 |
| Warehousing enterprises | 55 |
| Express enterprises | 15 |

Based the data, we use the method of Nash negotiation partner to determine the save cost of all participants, called $X = (x_A, x_B, x_C)$, known as the distribution strategy of the cooperative game, the constraint conditions for $X_i$ is:

![Table III. Value at Cost in Different Cooperation Pattern (Million Yuan)]

| Cooperation pattern | $A$ | $B$ | $C$ | $A, B$ | $A, C$ | $B, C$ | $A, B, C$ |
|---------------------|-----|-----|-----|--------|--------|--------|-----------|
| cost                | 80  | 100 | 60  | 170    | 120    | 150    | 200       |
\[
\max \prod_{i \in N} (c_i - x_i)
\]  

(6)

\[
s.t. \sum_{i \in N} x_i - C(N) = 0
\]  

(7)

\[
\Delta c < x_i < c_i
\]  

(8)

The model is employed for solving nonlinear programming problems as following:

\[
\max(80 - x_A)(100 - x_B)(60 - x_C)
\]  

(9)

\[
s.t. 50 < x_A < 80
\]  

(10)

\[
80 < x_B < 100
\]  

(11)

\[
30 < x_C < 60
\]  

(12)

\[
30 < x_C < 60
\]  

(13)

Using the Lingo software to solve the linear programming problem and result is \(x_A = 66.67\) (million yuan), \(x_B = 86.67\) (million yuan), \(x_C = 46.67\) (million yuan).

**Profit Distribution under the Mode of Joint Delivery**

The three joint companies are considered as the participators who are in the cooperative game. We suppose that A represents the small-and-medium-sized E-business company, B represents the logistics warehousing company and C represents the express company; then we get a set called N represented as \(N = \{A, B, C\}\) and the subset of N represented as \(N = \{\{A\}, \{B\}, \{C\}, \{A, B\}, \{A, C\}, \{B, C\}, \{A, B, C\}\}\) which means all the possible joint modes. According to the data provided by a modern logistics warehousing company, the following table shows the net profits under each joint mode (profits by separate delivery as benchmark):

Based on the table, we could get the value of the function of cooperative game mode called \(V(S)\) which is the profits under joint delivery and is calculated in the following ways:

(a) Separate delivery: no profits cause no costs saved: \(V(A) = V(B) = V(C) = 0\)
(b) Delivery by any two companies: \(V(AB) = 190\) (million yuan), \(V(AC) = 180\) (million yuan), \(V(BC) = 230\) (million yuan);
(c) Delivery by three companies together: \(V(ABC) = 420\) (million yuan)

| participant | A | B | C | A, B | A, C | B, C | A, B, C |
|------------|---|---|---|------|------|------|---------|
| profit     | 0 | 0 | 0 | 190  | 180  | 230  | 420     |

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According to the data above we could calculate the profits each company deserves with Shapley algorithm. The profits, also the distribution strategy of cooperative game, are represented as $X = \{X_1, X_2, X_3, \ldots, X_n\}$, in which $X_i$ is represented as:

$$W(|S|) = \frac{(n-|S|)!|S-i|!}{n!}$$  

$$X_i(V) = \sum_{S \subseteq S_i} W(|S|)[V(S) - V(S - i)]^{(i = A, B, C)}$$  

When the three companies conduct joint delivery together, the maximum of profits is 4.2 million. That is the joint profits $V(S)$ after joint delivery. Moreover, after distributing the profits with Shapley algorithm, we have the following three tables:

**TABLE V. PROFIT OF THE SMALL AND MEDIUM-SIZED E-COMMERCE ENTERPRISE A (10 THOUSAND YUAN).**

| $S$ | $\{A\}$ | $\{A, B\}$ | $\{A, C\}$ | $\{A, B, C\}$ |
|-----|---------|------------|------------|---------------|
| $V(S)$ | 0      | 190        | 180        | 420           |
| $V(S - \{A\})$ | 0      | 0          | 0          | 230           |
| $V(S) - V(S - \{A\})$ | 0      | 190        | 180        | 190           |
| $|S|\!$ | 1      | 2          | 2          | 3             |
| $W(|S|)\!$ | $\frac{1}{3}$ | $\frac{1}{6}$ | $\frac{1}{6}$ | $\frac{1}{3}$ |
| $X_i(V)$ | 0      | 31.7       | 30         | 63.3          | $\sum = 125$ |

**TABLE VI. PROFIT OF THE LOGISTIC ENTERPRISE B (10 THOUSAND YUAN).**

| $S$ | $\{B\}$ | $\{A, B\}$ | $\{B, C\}$ | $\{A, B, C\}$ |
|-----|---------|------------|------------|---------------|
| $V(S)$ | 0      | 190        | 230        | 420           |
| $V(S - \{A\})$ | 0      | 0          | 0          | 180           |
| $V(S) - V(S - \{A\})$ | 0      | 190        | 230        | 240           |
| $|S|\!$ | 1      | 2          | 2          | 3             |
| $W(|S|)\!$ | $\frac{1}{3}$ | $\frac{1}{6}$ | $\frac{1}{6}$ | $\frac{1}{3}$ |
| $X_i(V)$ | 0      | 31.7       | 38.3       | 80            | $\sum = 150$ |

**TABLE VII. PROFIT OF THE LOGISTIC ENTERPRISE B (10 THOUSAND YUAN).**

| $S$ | $\{C\}$ | $\{A, C\}$ | $\{B, C\}$ | $\{A, B, C\}$ |
|-----|---------|------------|------------|---------------|
| $V(S)$ | 0      | 180        | 230        | 420           |
| $V(S - \{A\})$ | 0      | 0          | 0          | 190           |
| $V(S) - V(S - \{A\})$ | 0      | 180        | 230        | 230           |
| $|S|\!$ | 1      | 2          | 2          | 3             |
| $W(|S|)\!$ | $\frac{1}{3}$ | $\frac{1}{6}$ | $\frac{1}{6}$ | $\frac{1}{3}$ |
| $X_i(V)$ | 0      | 30         | 38.3       | 76.7          | $\sum = 145$ |

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Analysis Results

According to the results of 5.1, under the mode of joint delivery the apportioned costs of each E-business company are 66.67 million, each logistics warehousing company are 86.67 million and each express company are 46.67 million. Comparing with separate delivery, the costs (E-business company 80 million, logistics warehousing company 100 million and express company 60 million) under apportionment is much more saved. Meanwhile, considering the joint companies’ profits themselves as an individual, this kind of results comfort to the rationality of both the individual and the participators.

According to the results of 5.2, the profits earned by the E-business company are $X_A(V)=1.25$ million, the logistics company with warehousing as the core are $X_B(V)=1.5$ million, the terminal express company are $X_C(V)=1.45$ million. Total profits are $X_A(V)+X_B(V)+X_C(V)=4.2$ million, and are in accordance with vested interest.

Conducting apportioned cost and the mechanism of profit distribution gives the joint delivery companies a reasonable distribution plan and solves the contradiction of fairness and efficiency.

CONCLUSION

To achieve rationalization and efficiency of delivery, joint delivery is necessarily needed. However, due to the multiple interests, conducting joint delivery still has many strict conditions which add more difficulties to it. Combining with the reasonable and scientific algorithm analysis, the strategy of apportioned cost and profit distribution when conducting joint delivery is presented in the thesis. There are some attentions should be mentioned. Firstly, make sure the rights and responsibilities of each joint company. Knowing exactly the rights and responsibilities helps to get a reference object when conducting data assessment and calculation of profit distribution and also rectifies the company’s working responsibilities and working range. Secondly, pay attention to the objectivity of information and data. It would damage the interests of part of joint companies if someone modifies the data. Therefore, it is necessary to make sure sharing information among all the joint companies and all the data are correct. Finally make sure the stability and flexibility of distribution. The direct cause of cooperation is to achieve efficient apportioned cost and reasonable profit distribution. Therefore, the approach above should be stable and fair and stabilized in the form of institutionalization. Meanwhile, to motivate the management role of apportioning costs and distributing profits, it is still necessary to make sure the flexibility of profit distribution

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