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Research Article

Research on the Cost Allocation of Joint Distribution of Agricultural Products based on Game Theory

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Abstract: Joint distribution in the process of circulation of agricultural products can reduce the cost of agricultural products circulation, improves the efficiency of logistics distribution, but for how to solve the problem of cost allocation has always been the major obstacle to the development of this model. The joint distribution model of agricultural products is presented in this study and then considers the problem of cost reduction in joint distribution of two agricultural products retailers. The amount of cost reduction is regarded as the income of distribution, which is distributed effectively by using game theory and resolve the problem of Cost allocation in joint distribution. Through the analysis of an example the joint distribution model can largely reduce the cost of distribution for agricultural products. Finally, through the distribution cost allocation verified the effectiveness and feasibility of this method of cost allocation.

Keywords: Agricultural products, cost allocation, game theory, joint distribution

INTRODUCTION

Agricultural products are primary food which cannot be long-term preserved at room temperature, including vegetables, fruits, meat, aquatic products, livestock products, etc. In recent years, our country's agricultural product circulation obtained a greater development, but the contradiction between the increasing agricultural products demand and the relative lag agricultural products distribution system is still the one of major problems affecting the supply of agricultural products. Due to the particularity of fresh agricultural products, the distribution pattern of fresh agricultural products is affected by various factors, it has a certain degree of complexity and related theoretical research is less. In order to establish a logistics distribution model that match with the circulation of agricultural products, improve the operational efficiency of the logistics of agricultural products, reduce the distribution cost, joint distribution gradually become the focus of the society.

Joint distribution in the process of agricultural products distribution can reduce the cost of agricultural products circulation; improve the efficiency of logistics distribution. But for how to solve the problem of cost allocation has always been a main obstacle for the further development of this model, so to strengthen the research of cost allocation for joint distribution is very important. We can extend the Shapley value of the crisp cooperative game to the HuKuhara-Shapley value based on interval number; create a cost allocation model while unit freight price is uncertain (Weisha and Qiang, 2007). A cost apportionment model by using Game theory to fix on the cost allocation has been set up by Song *et al*. (2006). To deal with the problems existing in cost allocation, we can take together the game theory and the economic order quantity model to propose a cost allocation algorithm for the joint distribution (Weili *et al*., 2010). We must focus on the cost allocation algorithms, which are different from each other, under different combinative meaning which lead different cost saving (Zhijian *et al*., 2004). A cost allocation mode of joint distribution alliance base on the Raiffa solution has been studied by Xu *et al*. (2008). In the real environment, competitive negotiation is a simple and easy method of cost allocation. However, these negotiations have time cost and needs to consider the patient degree in the negotiation and the degree of patient is depending on the alliance member's situation. The size of patient degree will affect the alliance member's position in the negotiation and influence the result of cost allocation in joint distribution. The Rubinstein bargaining model can consider that the degree of negotiation's patient as well as the time cost of negotiation, it can make up for the deficiencies in former study and has a very important significance for the problem of cost allocation in the process of agricultural products distribution.

This study presents the joint distribution model of agricultural products and consider the problem of the

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joint distribution cost reduction by two agricultural products retailers (agricultural community supply point, supermarket supply points as well as large enterprises), regard the amount of cost as the income of co-distribution, assign the income effectively by game theory and then solve the problem of cost allocation of the joint distribution. Finally, an example verified the operability and feasibility of this method of cost allocation.

Problem description: The data show that China's logistics costs generally total cost of 20 to 30%, fresh agricultural products reached more than 60% of the logistics costs, while the cost in developed countries is about l0%. In addition, the fresh agricultural products in China, such as fruits and vegetables, loss 25 to 30% in harvesting, transport and storage, while the loss rate of fruits and vegetables in developed countries is less than 5% (Haoxiong *et al*., 2011). Distribution is the key link in agricultural product logistics. If we can choose the most reasonable distribution model of agricultural products, it will greatly reduce the cost of agricultural products logistics and improve the efficiency of distribution as a whole. In the real economic environment, joint distribution alliance which is made up of retailers would help to solve the problems in the circulation of agricultural products logistics. As shown in Fig. 1, compared with the traditional model of agricultural products distribution, joint distribution can partly solve the problems of wasting time, the high transportation cost and traffic congestion, the fragmented transportation of agricultural products can be integrated into low-cost vehicle transportation. This model improved the real load rate of transportation vehicle, achieved the optimal allocation of the distribution of resources, avoided the unnecessary staggered transport, reduced the number of transport vehicles, eased the traffic pressure and reduced the pollution of the city and so on.

It can be seen that joint distribution model is of very great significance in practice, but this model has never received any large develop. The main reason is that the cost of joint distribution cannot achieve a fair allocation between enterprises. In the real environment, competitive negotiation is a simple and easy method of cost allocation. The negotiation of cost allocation between participants is a process of repeated game, bargaining is the nature of this negotiation between the two sides. In the market environment, the enterprises which participate in market competition also have many cooperation opportunities. Enterprises can refuse to cooperate and looking for the next opportunity of cooperation in cooperation with unfavorable circumstances, but the process of this seeking partner has the price and it's related to the degree of enterprise urgent to cooperate. When an enterprise is eager to get economic interests through cooperation, give up every opportunity to cooperate will cause larger loss to the enterprise (Yong and Xiutai, 2003). The Rubinstein

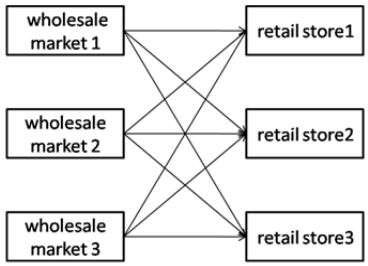

Fig. 1: Traditional model of agricultural products distribution

bargaining model considered the factor of time cost that is the discount factor's influence on the outcome of bargaining. This study considered the question of cost reduction of joint distribution alliance constituted by two agricultural products retailers, regarded the volume of cost reduction as the income of distribution, allocated the income effectively by Rubinstein bargaining model in the game theory and then tried to solve the problem of cost allocation in joint distribution indirectly.

METHODOLOGY

In the process of agricultural products distribution, the joint distribution model is superior to the traditional distribution model and it will generate cost reduction. We can regard the cost reduction as the income of distribution and then deduct the respective income of distribution from the cost of distribution of agricultural products retailers, finally we will get the solution to the problem of cost allocation for every retailer. For the joint distribution alliance constituted by two agricultural products retailers, this alliance only has two participants, the participants are rational individuals and pursue their maximization of profit respectively. So how to make a fair distribution of income has become a crucial problem. This study uses the Rubinstein bargaining model to allocate the income of distribution for two agricultural products retailers. Rubinstein proved creatively that there is only one sub-game perfect Nash equilibrium in a bargaining game with non-time limit:

If the participant 1 first proposes the assignment plan of income, we can get the results:

$$S_1 = \frac{(1-\delta_2)}{1-\delta_1\delta_2},\ S_2 = \frac{\delta_2(1-\delta_1)}{1-\delta_1\delta_2}$$

If the participant 2 first proposes the assignment plan of income, the results are as follows:

$$S_1 = \frac{\delta_1(1-\delta_2)}{1-\delta_1\delta_2},\ S_2 = \frac{1-\delta_1}{1-\delta_1\delta_2}$$

In the above equation,

s_1, s_2 : The proportion of income distribution for two participants

Table 1: Evaluation relations of every aspect for patience degree coefficient

Average transport volume	Rate of idle running	Discrete degree of retail stores' distribution	Comments
Low	High	High	Low
Relatively low	Relatively high	Relatively high	Relatively low
Medium	Medium	Medium	Medium
Relatively high	Relatively low	Relatively low	Relatively high
High	Low	Low	High

δ_1, δ_2 : The discount factors of two sides and it means the degree of participant's patience in the negotiations

In the joint distribution alliance composed with two agricultural products retailers, the degree of patience depend on the average transport volume of retailers, the rate of idle running and the degree of dispersion of retail stores. If the average transport volume of retailers are few, the rate of idle running is very high and the degree of dispersion of retail stores is very scattered, the enterprise will be eager to cooperate to reduce the logistic cost through joint distribution and it will not have many chances to propose the assignment plan of income in the negotiations. This phenomenon caused the unequal position of retailers in the negotiation.

Assuming that the degree of retailer's patience is mainly determined by the average transport volume of retailers, rate of idle running and the discrete degree of retail stores distribution.

This study uses the fuzzy integrated evaluation to evaluate the degree of retailer's patient. Firstly, we should determine the set of evaluation factors:

$$U = \{\text{Average transport volume of retailers , Rate of idle running , the discrete degree of retail stores distribution.}\}$$

Three factors have different effects on the degree of retailer's patience, we can entrust the different weight to every element, the set of weight is A = {a_1, a_2, a_3}, weight should be normalized, non-negative and $\sum a_i = 1, a_i \geq 0$.

Then establish the evaluation comments of factors:

$$v = \{\text{low, relatively low , medium , relatively high , high}\}$$

And entrust the value to the evaluation combination of factor:

$$v_1 = \{0.1, 0.2, 0.5, 0.7, 0.9\}$$

In order to obtain the matrix of fuzzy relationship, we can invite correlation expert to evaluate the degree of agricultural products retailer's patience. We can evaluate these factors according to the Table 1 of relationship between three factors with the comments.

If we want to evaluate these factors, we should invite the experts to evaluate the degree of retailer's patience and give the corresponding comments. Then if make a statistical analysis of the results of the evaluation of each expert, we can get the value of every factor in every grade. In this way, we can get the fuzzy vector that affecting the degree of retailer's patience. r_1 Represents the average transport volume of retailers, r_2 represents the rate of idle running and r_3 represents discrete degree of retail stores' distribution.

These fuzzy vectors can be composed of a fuzzy relation matrix R to evaluate the degree of patience:

$$R = \begin{bmatrix} r_1 \\ r_2 \\ r_2 \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ r_{31} & r_{32} & r_{33} & r_{34} & r_{35} \end{bmatrix}$$

And then considered the three influencing factors regarding the weight set of patient's degree, B is the result of fuzzy integrated evaluation:

$$B = A \times R$$

$$B = [a_1 \ a_2 \ a_3] \cdot \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} & r_{15} \\ r_{21} & r_{22} & r_{23} & r_{24} & r_{25} \\ r_{31} & r_{32} & r_{33} & r_{34} & r_{35} \end{bmatrix} = [b_1 \ b_2 \ b_3 \ b_4 \ b_5]$$

Normalized the result of fuzzy integrated evaluation:

$$B' = [b_1' \ b_2' \ b_3' \ b_4' \ b_5']$$

Finally we can get the value of patience degree:

$$\delta_{1,2} = B' v_1^T (b_1' \ b_2' \ b_3' \ b_4' \ b_5') \cdot \begin{bmatrix} 0.1 \\ 0.3 \\ 0.5 \\ 0.7 \\ 0.9 \end{bmatrix}$$

$$= 0.1b_1' + 0.3b_2' + 0.5b_3' + 0.7b_4' + 0.9b_5'$$

D represents the income from the joint distribution by two agricultural products retailer. If retailer 1 first proposes the plan of income assignment, then two retailer's income distribution is as follows:

$$D_1 = \frac{1-\delta_2}{1-\delta_1\delta_2} D \text{ , } D_2 = \frac{\delta_2(1-\delta_1)}{1-\delta_1\delta_2} D$$

If, respectively represent the cost of distribution alone and then the cost they should be share in the joint distribution is as follows:

$$C_1^{'} = C_1 - \frac{1-\delta_2}{1-\delta_1\delta_2} D \text{ , } C_2^{'} = C_2 - \frac{\delta_2(1-\delta_1)}{1-\delta_1\delta_2} D$$

Similarly, if retailer 2 first proposes the plan of income assignment, the cost they should be share in the joint distribution is as follows:

$$C_1^{'} = C_1 - \frac{\delta_1(1-\delta_2)}{1-\delta_1\delta_2} D, C_2^{'} = C_2 - \frac{(1-\delta_1)}{1-\delta_1\delta_2} D$$

RESULTS AND DISCUSSION

In the process of distribution of agricultural products, joint distribution can improve the efficiency of distribution, reduce the cost of agricultural product distribution. Fair and reasonable cost allocation scheme is the key to conduct joint distribution. The Rubinstein bargaining model based on game theory in this study is on the basis of considering the degree of retailer's urgent to cooperate, establishes the plan of income allocation between two retailers and then resolve the problem of cost allocation in joint distribution. Finally, we have verified the effectiveness and feasibility of this method of cost allocation through an example. But in the actual process of agricultural products circulation, many factors can affect the joint distribution and there are many factors that can influence finally cost of distribution and uncertainty factors will make the results of the model more complex, which may lead to more complex results and this is the next step for the research to solve.

Example analysis: Assuming that the joint distribution center of agricultural products P distribute agricultural products to the four retail stores 1, 2, 3, 4. Stores 1 and 3 affiliated to the retailer A, stores 1 and 3 affiliated to the retailer B. As shown in Fig. 2, the average demand of retail stores are respectively three tons, five tons, seven tons, nine tons. This study is under the assumption that distribution cost = unit transportation cost* amount of transport* traffic Volume. Unit transportation cost is shown in Table 2 (Fig. 3).

According to the graphs, the total cost of the distribution is:

$$C_T = 4\times3\times15+3.6\times5\times12+3.4\times7\times10+$$
$$2.5\times9\times13=180+216+238+292.5=926.5$$

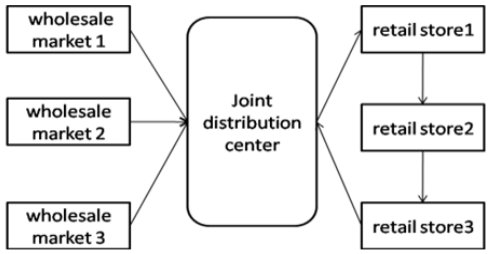

Fig. 2: Joint distribution of agricultural products

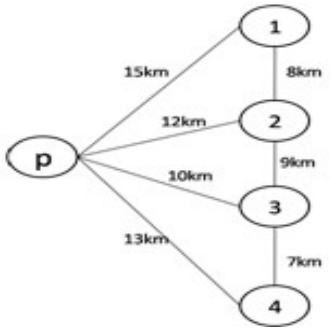

Fig. 3: Map of transportation routes

Table 2: Unit transportation cost

Traffic volume	Unit transportation cost
3	4.0
5	3.6
7	3.4
8	3.0
9	2.5
15	1.6
24	0.5

If four retail stores carry on the joint distribution, the total distribution cost is:

$$C_{1,2,3,4} = 0.5\times24\times13+1.6\times15\times7+3$$
$$\times8\times9+4\times3\times8=156+168+216+96=636$$

This shows that when the retail stores carry on the joint distribution, we can save much cost of distribution and regard the cost-saving as the income of distribution. D = 926.5 - 636 = 290.5. And then allocate the income of distribution by Rubinstein bargaining model and fuzzy integrated evaluation. We can assume that $\delta_A = 0.54, \delta_B = 0.45, \delta_A > \delta_B$. Retailer A will have more chances to propose the plan of income assignment, the two retailer's income of distribution are:

$$D_A = \frac{1-\delta_B}{1-\delta_A\delta_B} D = \frac{1-0.45}{1-0.54\times0.45} \times 290.5 \approx 211.06$$

$$D_B = \frac{\delta_B(1-\delta_B)}{1-\delta_A\delta_B} D = \frac{0.45(1-0.54)}{1-0.54\times0.45} \times 290.5 \approx 79.44$$

Retailer A participates in joint distribution, the cost that it should share in the joint distribution is:

$$C_A = C_1 + C_3 - D_A = 180 + 238 - 211.06 = 206.94$$

The cost that retailer B should share in the joint distribution is:

$$C_B = C_2 + C_4 - D_B = 216 + 292.5 - 79.44 = 429.06$$

CONCLUSION

According to the above calculation, the total cost of joint distribution between retailer A and retailer B is 636. For $\delta_A > \delta_B$, retailer A has more chances to propose the income assignment plan ,the income of retailer A in the joint distribution is 211.06 and that is higher than the income of retailer B. and then make the cost of retailer A,B distribute alone minus the income of distribution. We can get the cost that retailers should share in the joint distribution and retailer's cost is respectively 206.94 and 429.06. But along with the joint distribution ongoing, the plan of cost allocation is not the only determination. For example, the retailer which has high rate of idle and low transport volume before will reduce the cost and improve rate of loading of vehicles and it will affect the degree of patience in the cost allocation negotiation. Meanwhile, this would also change the retailer's position in the alliance. The retailer which is at unfavorable position in the negotiation will have more opportunity to fist propose the plan of income assignment in the bargaining process, so the retailer's position in the negotiation will be changed and that will affecting the final results of the cost allocation.

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