Allocation of Cost Savings in an O2O Information-sharing Supply Chain

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Abstract. This paper investigates how information sharing in O2O (online-to-offline) business model, in which the platform is a website or mobile application that acts as a liaison between physical stores and Internet users, influences allocation of cost savings of a four-player supply chain with an upstream supplier, a downstream retailer, logistics service provider and platform. We aim to maximize cost saving through information sharing in different coalitions of O2O business models, which take advantage of information sharing among demand and product-inventory data collected by the platform for increasing in-store sales. We analyze the effect of cost savings in various feasible coalitions followed by the computation of the expected cost incurred in various coalitions. This paper adopts the Shapley value and Banzahf index to allocate cost savings to associated stakeholders in the chain. We present numerical analysis to examine the impacts of information sharing on cost savings in different allocation scheme

Keywords: Information sharing; Cost saving; O2O business model

1. INTRODUCTION

In this paper, we aim to find out how online-to-offline (O2O) business models can influence supply chain in an efficient way by information sharing. As the core of information flow system, virtual platform plays the role of congregating demand data as well as liaison of upstream supplier, downstream retailers and logistics provider. Therefore, we want to know that under the structure of O2O business model, where the platform is necessary, how platform interacts with other players to maximize the allocation of cost savings in the whole supply chain, how information sharing is conducted in various coalitions, which bring more profits and maximize cost savings and what mechanism could distribute allocation of cost savings brought by coalitional schemes in an unique and efficient way to motivate and stabilize participants in coalitions.

This paper is organized as follows. In §2, we presents a model of an O2O business model supply chain with four-level players. We develop different coalitions with different information-transduction pathway to simulate real situations of information flow for achieving the optimal order-up-to level stakeholders in the chain. Moreover, we analyze the benefits (cost savings) of information sharing in different coalitions, and we determine which coalitions or players have significant impacts on the benefits of information sharing in characteristic form. After knowing characteristic values, in §3, we present the conditions for cooperation in the four-level system to ensure the stability and feasibility of coalitions. In particular, we use Shapley value and Banzahf index to distribute cost allocations to stakeholders in the system to obtain a unique balance and reach maximum efficiency. The paper ends with a discussion in §4.

2. MODEL ANALYSIS

2.1 Problem Description

To simplify the analysis, there is only a single product traded in the supply chain inclusive of four players. The upper stream of the supply chain is the manufacture, the logistics service provider stands for middle stream. The retailer is the downstream member and the platform plays the role of intermediary of information booth. Customers can reach the product information and place orders through the platform, then the platform retrieves demand information from end users and shares it with the upper stream manufacture, downstream retailer or logistics service providers to corporate for cost savings and reach learning effects rapidly.

The demand data from ultimate customers is the most important piece of information worthy of sharing. We define the demand information shared in these coalitions as the demand data confronted with the platform and assume that the end demand is forecasted by the simple auto correlated AR(1) process:

$$D_t = d + \rho D_{t-1} + \varepsilon_t, \quad (1)$$

where D_t represents the consumption rate in period t, d is a positive contant, ρ is a autocorrelation parameter with $|\rho| \leq 1$ (The value of information sharing in a two-level supply chain (Lee et al. 2000) provided empirical evidence to show that for most products the autocorrelation coefficient ρ is positive.), and ε_t is the error term that is identically and independently distributed (i.i.d.) with a symmetric distribution (e.g., normal) having mean 0 and variance σ^2. After predicting the future demand, we treat the model as demand process for retailer's and manufacture's order quantity and compute cost savings generated by information sharing in this section. When ρ = 0, the end demand is reduced to $D_t = d + \varepsilon_t$, which is independent on the past demand information. In that way, end-demand information sharing of last term does not change the retailer and the manufacture's ordering decisions.

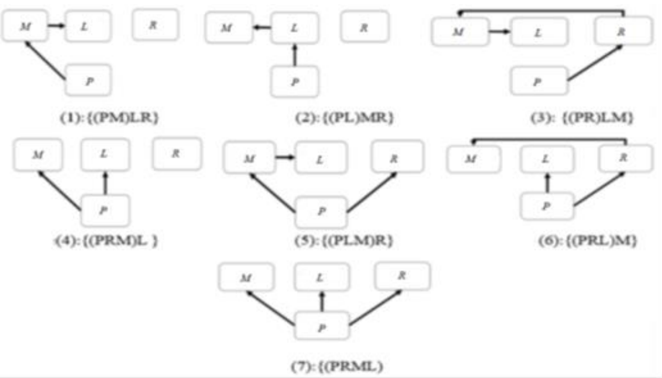

Figure 1: Four supply chain members P, M, L and R.

We now derive the expression for the order-up-to-level C_t, that minimizes the total expected holding and shortage costs in period t. We assume the retailer's optimal order-up level C_t, at the end of period t is

$$C_t = d + \rho D_{t-1} + k\sigma, \quad (2)$$

where $k = \emptyset^{-1}[s/(s+h)]$; h and s denote unit holding cost and the unit shortage cost respectively; $\emptyset^{-1}$ is the distribution function of the standard normal random variable (see Lee et al. 2000).

After considering the cost of demand data and clarifying the relationship between demand information and different players in the supply chain, we seek to find out the stable and effective coalitional structures for cost saving in the system. As a result, in the whole possible coalitional structures, platform would never be absent in different feasible coalitions. In this case, we can find out seven feasible coalitions:

The paper examines the cases of specific allocation schemes to analyze the cost savings effects. Therefore, we still assume the original structure {P, M, L, R} as a base to compare the difference of cost before cooperation with post-cooperation. The supply chain members do not share end-demand information in original situation. For this case, the expected costs of the manufacturer, the logistics service provider, the retailer and the platform are M_{P1}, L_{P1}, R_{p1}, and PL_{p1} respectively.

To illustrate the examination, we refer to Figure 1 that depicts seven possible coalitional structures for information sharing among supply chain members. Figure 1 corresponds to the situation where platform and manufacture can form a two, three, or four-player coalitions. The manufacture can therefore receive end-demand information from the platform. In {(PM)LR} case, the expected costs of the manufacturer, the logistics service provider, the retailer and the platform are M_{P2}, L_{P2}, R_{p2}, and PL_{p2} respectively. The remaining parts Figure 1 (2)-Figure 1 (7) have similar interpretations.

2.2 The Cost of Supply Chain Members in Different Coalitions

In the supply chain under study, as the innovative O2O business model is operated, the platform must be considered as the most important player in different coalition who leads the direction of information flow. Hence, after we identify all possible coalitional structures, we compute the unit cost of information sharing of the platform first.

Let ic>0 be the fixed operation cost of platform, which is spent on managing its customer relationship, search behavior and purchase intention and is larger than variable cost of other players; let the information transmission cost of platform without partners be 1, which stands for that the cost of coordinating information even there is no receiver. We also let r_{Pi} denote number of paths of information flow that the platform share with partners for coalition p_i. As constructing a database of customer relationship and maintaining a virtual platform would be an inevitable expenditure, the platform who expands its boundary to offer information service to more partners in the supply chain would realize economies of scale to decrease unit cost of operation of platform gradually. In this way, there would be inverse relationship between fixed information transmission cost of platform without partners plus number of paths of information flow for coalition p_i: $r_{Pi} + 1$, and fixed operation cost of platform, ic, then the unit cost of information sharing of the platform is

$$ic \cdot 1/(r_{Pi} + 1). \quad (3)$$

The reciprocity stands for economies of scale that can help the platform gain more profits and reduce average cost at the same time from sharing information with more partners (i.e. advertising income, commission from sale).

The production plan scheduled by manufacture relies on the actual demand at the end of the period t-1, so we make setup cost in the leading time in the coalition structure p_i be based on retailer's orders in the previous term. Let s_m be the shortage cost at manufacture's level per unit and h_m be the holding cost at manufacture's level per unit, then the set up cost would be unit holding cost h_m or shortage cost s_m multiplied by retailer's orders in last term C_{t-1} and growth rate of order, $(C_t - C_{t-1})/C_{t-1}$. In this case, the cost of manufacture without receiving and transmitting information is

$$s_m \cdot C_{t-1} \cdot \frac{C_t - C_{t-1}}{C_{t-1}} \text{ , if } \quad C_t \geq C_{t-1} \tag{4}$$

$$-h_m \cdot C_{t-1} \cdot \frac{C_t - C_{t-1}}{C_{t-1}}, \text{ if } \quad C_t < C_{t-1}. \tag{5}$$

Practically, manufactures usually schedule their production plan according to retailer's orders in the previous term C_{t-1}, therefore, growth rate of order $(C_t - C_{t-1})/C_{t-1}$, represents the rate of difference between current orders and production plan, equal to holding rate or shortage rate of manufacture.

For the logistics service provider, let *tc* be the truck capacity and *Tr* be the transportation cost per path and per truck capacity. Let L_{pi} be the number of paths of logistics flow that a truck runs for in coalitional scheme pi. In this model, we fix L_{pi} at two due to consideration of receiving goods from the manufacture and delivering goods to the retailer. We assume that there would be only one truck in transit at one time, then the cost of logistic providers is

$$Tr \cdot L_{pi} \cdot tc. \tag{6}$$

On the other hand, if the retailor prepares stock up based on orders of last term, they would confront with holding cost and shortage cost in current period. We let $C_t = \ d + \rho D_{t-1} + k\sigma$ be retailer's order-up-to level in current period t. In this way, both kinds of cost are computed through multiplying order up level in the previous term, C_{t-1} , and growth rate of order, $(C_t - C_{t-1})/C_{t-1}$, is equal to holding or shortage rate of retailor in current period, to obtain the quantity of holding or shortage. Let s_r be the shortage cost at retailer's level per unit, and let h_r be the holding cost at retailer's level per unit. As a result, total cost of retailor in the supply chain is

$$s_r \cdot C_{t-1} \cdot \frac{C_t - C_{t-1}}{C_{t-1}} \text{ if } \quad C_t \geq C_{t-1} \tag{7}$$

$$-h_r \cdot C_{t-1} \cdot \frac{C_t - C_{t-1}}{C_{t-1}} \text{ if } \quad C_t < C_{t-1} \tag{8}$$

where h_r stands for unit holding cost and s_r stands for shortage cost at retailer's level.

Therefore, the minimizing cost function in different coalitional structure p_i is

$$Min \quad [(Tr \cdot L_{pi} \cdot tc) + (s_m \cdot C_{t-1} \cdot \frac{C_t - C_{t-1}}{C_{t-1}}) + (s_r \cdot C_{t-1} \cdot \frac{C_t - C_{t-1}}{C_{t-1}}) + (ic \cdot \frac{1}{r_{Pi}+1})] \text{ if } \quad C_t \geq C_{t-1},$$

$$Min \quad [(Tr \cdot L_{pi} \cdot tc) - \ (h_m \cdot C_{t-1} \cdot \frac{C_t - C_{t-1}}{C_{t-1}}) - \ (h_r \cdot C_{t-1} \cdot \frac{C_t - C_{t-1}}{C_{t-1}}) + (ic \cdot \frac{1}{r_{Pi}+1})] \text{ if } C_t < C_{t-1}.$$

However, since our model put emphasis on influence on cost of information sharing, therefore we let $|\delta|, |\alpha| \leq 1$ be a revise cost due to information sharing. Whenever a player (i.e. manufacture or retailer) receives information from others, it can prevent some errors of prediction.

Now we compute the cost of each players in different coalitional schemes (i.e., $M_{P1}, \dots, M_{P8}, L_{P1}, \dots, L_{P8}, PL_{P1}, \dots, PL_{P8}, R_{P1}, \dots, R_{P8}$) for all eight coalitional structures. The situation before cooperation, where every member in the supply chain does not save any cost, is unreasonable in practice due to the fact that the platform would not exist independently. However, we still assume it to be the prime state, where each player in the coalitions operates their own business with original cost, to compare allocation of cost savings with other coalitional schemes.

Coalition {(PM)LR}:

In the coalition {(PM)LR}, the platform only shares information with manufacture provider. Then the manufacture would transmit information of customer orders to the logistics provider, so that logistics provider can conduct transport management and schedule for the transport process to retailer. Thus, the information sharing also occur among L and M.

Total cost =

$$\begin{cases} [Tr \cdot (1-\delta) \cdot 2 \cdot tc] + \left[s_m \cdot C_{t-1} \cdot \dfrac{C_t - C_{t-1}}{C_{t-1}} \cdot (1-\delta) \cdot (1+\alpha)\right] \\ \quad + \left[s_r \cdot C_{t-1} \cdot \dfrac{C_t - C_{t-1}}{C_{t-1}}\right] + \left[ic \cdot \dfrac{1}{2}\right] \text{ if } \quad C_t \geq C_{t-1} \\ [Tr \cdot (1-\delta) \cdot 2 \cdot tc] - [h_m \cdot C_{t-1} \cdot \dfrac{C_t - C_{t-1}}{C_{t-1}} \cdot (1-\delta) \cdot (1+\alpha)] \\ \quad -[h_r \cdot C_{t-1} \cdot \dfrac{C_t - C_{t-1}}{C_{t-1}}] + [ic \cdot 1/2] \quad \text{if } C_t < C_{t-1} \end{cases}$$

Coalition {(PL)MR }:

In the coalition {(PL)MR}, the platform only shares information with logistics provider. Then the logistics provider would transmit information of customer orders to the manufacture, so that manufacture would prepare stock accurately for retailer's orders. Thus, the information sharing also occurs among L and M.

Total cost=

$$\begin{cases} [\mathrm{Tr}\cdot(1-\delta)\cdot(1+\alpha)\cdot 2\cdot tc]+\left[s_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\right] \\ \quad +\left[s_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\right]+\left[ic\cdot\dfrac{1}{2}\right] \quad \text{if} \quad C_t\geq C_{t-1} \\ [\mathrm{Tr}\cdot(1-\delta)\cdot(1+\alpha)\cdot 2\cdot tc]-\{h_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\} \\ \quad -\{h_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\}+\{ic\cdot 1/2\} \text{ if } C_t<C_{t-1} \end{cases}$$

Coalition {(PR)ML}:

In the coalition {(PR)ML}, the platform only shares information with retailer. Since only the downstream firm get demand information, the retailer would give orders up to the manufacture in preparation for stock. Then the manufacture would transmit information of customer orders to the logistics provider. In this way, the logistic provider can conduct transport management and schedule for the transport process. Thus, the information sharing also occur among R, L and M.

Total cost=

$$\begin{cases} [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]+\left[s_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\cdot(1+\alpha)\right] \\ +\left[s_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)(1+\alpha)\right]+\left\{ic\cdot\dfrac{1}{2}\right\} \quad \text{if} \quad C_t\geq C_{t-1} \\ [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]-[h_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\cdot(1+\alpha)] \\ -[h_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)(1+\alpha)]+\{ic\cdot 1/2\} \text{ if } C_t<C_{t-1} \end{cases}$$

Coalition {(PML)R}:

In the coalition {(PML)R}, the platform shares information with manufacture and logistic provider. Since they get enough information, the logistic provider can conduct transport management and schedule for the transport process right after receiving products from the manufacture. Besides, it could directly ship the orders to retailer, and the customer can just pick up their products faster. In this case, the retailer plays a passive role and does not have to make orders to the manufacture due to that the manufacture already has demand information.

Total cost=

$$\begin{cases} [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]+\left[s_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\right] \\ \quad +\left[s_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\right]+\left\{ic\cdot\dfrac{1}{3}\right\} \quad \text{if} \quad C_t\geq C_{t-1} \\ [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]-[h_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)] \\ \quad -[h_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}]+\{ic\cdot 1/3\} \quad \text{if } C_t<C_{t-1} \end{cases}$$

Coalition {(PMR)L}:

In the coalition {(PMR)L}, the platform shares information with manufacture and retailor. After getting the demand information from platform, the manufacture would transmit information of customer orders to the logistics provider. In this way, the logistic provider can conduct transport management and schedule for the transport process to deliver goods on time to retailor. Thus, the information sharing occurs among R, L and M.

Total cost=

$$\begin{cases} [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]+\left[s_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\cdot(1+\alpha)\right] \\ \quad +\left[s_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\right]+\left\{ic\cdot\dfrac{1}{3}\right\} \text{if} \quad C_t\geq C_{t-1} \\ [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]-[h_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\cdot(1+\alpha)] \\ \quad -[h_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)]+\{ic\cdot 1/3\} \ \textit{if} \ C_t<C_{t-1} \end{cases}$$

Coalition {(PLR)M}:

In the coalition {(PLR)M}, the platform share information with logistics provider and retailor. After getting the demand information from platform, the retailer would give orders up to the manufacture. Thus, the information sharing occur among L, R and M.

Total cost=

$$\begin{cases} [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]+[s_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)] \\ +[s_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\cdot(1+\alpha)]+\{ic\cdot 1/3\} \text{ if } \quad C_t\geq C_{t-1} \\ [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]-[h_m\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)] \\ -[h_r\cdot C_{t-1}\cdot\dfrac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)\cdot(1+\alpha)]+\{ic\cdot 1/3\} \text{ if } C_t<C_{t-1} \end{cases}$$

Coalition {(PMLR)}:

In the coalition {(PMLR)} which would fully exert its effect of information sharing, the platform would disseminate demand information to other three players. In the case, the other three players can save the cost of transmitting information to each other. At the same time, the platform can play the full role of information coordinator and realize economies of scale of information sharing.

Total cost=

$$\begin{cases} [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]+[s_m\cdot C_{t-1}\cdot\frac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)] \\ +[s_r\cdot C_{t-1}\cdot\frac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)]+\{ic\cdot 1/4\} \text{ if } \quad C_t\geq C_{t-1} \\ \\ [\mathrm{Tr}\cdot(1-\delta)\cdot 2\cdot tc]-[h_m\cdot C_{t-1}\cdot\frac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)] \\ -[h_r\cdot C_{t-1}\cdot\frac{C_t-C_{t-1}}{C_{t-1}}\cdot(1-\delta)]+\{ic\cdot 1/4\} \text{ if } C_t< C_{t-1} \end{cases}$$

3. ANALYSIS AND DISCUSSION

3.1 Model and Analysis of the Cooperative Game

To find the characteristic-function values of various coalitions, we compute total cost savings for each possible coalition in which the participants share demand information faced by their downstream members in the last section. Then in this part, we develop a cooperative game in characteristic-function form as well as analyzing models to find the appropriate allocation scheme which "fairly" allocates expected cost savings for stakeholders in the supply chain.

In our paper, we discuss the problem of O2O model, a business strategy that draws potential customers from online channels to physical stores. As a result, in this paper, the definition of O2O coalition is given as follows:

Assumption 1. *In an O2O business information-coordinated cooperative game, a scheme for allocating cost savings among all members in supply chain in a coalition is valid only if the platform, online channel, is inclusive in any multi-player coalitions and plays the coordinator of information sharing.*

3.2 An O2O Cooperative Game in Characteristic Function

A cooperative game is given by specifying a value for every coalition. Formally, the (coalitional game) consists of a finite set of players *N*, called the grand coalition. In our paper, the grand coalition is a four-person game. In practice, with the definition of O2O model which always includes online channel, we can obviously define some coalitions as infeasible coalitions and block them from all possible sets of players. Therefore, we still have seven feasible coalitions: {(PL)MR}, {(PM)LR}, {(PR)LM}, {(PML)R}, {(PLR)M}, {(PMR)L}, {(PMLR)}.

In the theory of cooperative games, the characteristic value is the minimum collective payoff that the coalition can attain with a set of players. In our paper, the characteristic value of a coalition is the amount of cost saving and improvements in profits the coalitions could at least attain from its own effort when the coalitions is feasible in O2O model: v(PL), v(PM), v(PR), v(PMR), v(PML), v(PLR), v(PMLR).

A characteristic function $\mathscr{v}: 2^N \to \mathbb{R}$ from the set of all possible coalitions of players to a set of cost allocations that satisfies $\mathrm{v}(\emptyset)=0$. The function describes how much cost allocations a set of players can save by forming a coalition. Even more, after we obtain characteristic values, we will present some conditions for cooperation in the four- level system to ensure the stability and feasibility of coalitions. On the other hand, we use the Shapley value and Banzahf index to distribute cost allocations to stakeholders in the system to get unique allocation scheme.

We now compute the characteristic values of all possible coalitions. First, the characteristic value of an empty coalition is naturally zero: $\mathrm{v}(\emptyset)=0$.

Next, we are going to discuss single-player coalitions. According to the definition of O2O business information-coordinated cooperative game, there is no possibility that the platform independently exists under the condition that other members but it makes up coalitions. If other player in the supply chain can coordinate and have a better result of allocation of cost savings without involvement of platform, then the business model of O2O would not be efficient. In that case, the platform would be a meaningless dummy player, and there is no need for constructing the platform.

On the other hand, if the retailer, manufacture, and logistics service provider do not share information with each other, then the individuals will have no cost savings, and the characteristics value is zero.

Next, we consider other feasible two-player coalitions in the O2O business model: the characteristic value v(PM) of the coalition {(PM)LR} is the minimum expected allocation of cost savings that the two players can create when only they cooperate. Therefore, the retailer and the logistics service provider don't share demand information with each other. Thus, we can get the value:

$$\mathrm{v(PM)} = \mathrm{Min}\ [(PL_{P1}-PL_{P2}),(PL_{p1}-PL_{p5}),(PL_{p1}-PL_{p6})] + \mathrm{Min}\ [(M_{P1}-M_{P2}),(M_{P1}-M_{P5}),(M_{P1}-M_{P6})].$$

Also, the characteristics functions of other feasible coalitions: v(PR), v(PL), are calculated as follows:

$$\mathrm{v(PR)} = \mathrm{Min}\ [(PL_{P1}-PL_{P4}),(PL_{p1}-PL_{p6}),(PL_{p1}-PL_{p7})] + \mathrm{Min}\ [(R_{P1}-R_{P4}),(R_{P1}-R_{P6}),(R_{P1}-R_{P7})],$$

$$\mathrm{v(PL)} = \mathrm{Min}\ [(PL_{P1}-PL_{P3}),(PL_{p1}-PL_{p5}),(PL_{p1}-PL_{p7})] + \mathrm{Min}\ [(L_{P1}-L_{P3}),(L_{P1}-L_{P5}),(L_{P1}-L_{P7})].$$

Now we consider the three-member coalitions and the grand four-player coalition. The characteristic value v(PML) of the coalition {(PML)R} is the minimum expected allocation of cost savings that the three players can create when only they cooperate. Therefore, we calculate the cost savings incurred at the manufacture, platform and logistics service provider level. In this case, the retailer does not share demand information with any other member. Then when the other three members share information with each other, they can gain the expected cost savings:

$$\text{v(PML)} = (PL_{p1} - PL_{p5}) + (M_{P1} - M_{P5}) + (L_{P1} - L_{P5}).$$

Similarly, when calculating the coalitions v(PMR), v(PLR) & v(PMLR), we can get:

$$\text{v(PMR)} = (PL_{p1} - PL_{p6}) + (M_{P1} - M_{P6}) + (R_{P1} - R_{P6}),$$

$$\text{v(PLR)} = (PL_{p1} - PL_{p7}) + (L_{P1} - L_{P7}) + (R_{P1} - R_{P7}),$$

$$\text{v(PMLR)} = (PL_{p1} - PL_{p8}) + (L_{P1} - L_{P8}) + (R_{P1} - R_{P8}) + (M_{P1} - M_{P8}).$$

3.3 Solution Concepts

3.3.1 Shapley Value with Banzhaf Power Index

In the cooperative game theory, the Shapley value is a solution concept assigning a unique distribution of a total surplus generated by the coalition among all players. That is to say, the Shapley value distribute the total gains and provides unique imputations in assumption that all members collaborate fairly by an arbitrator. The unique Shapley values $\emptyset = (\emptyset_1,\ldots, \emptyset_n)$ are determined by $\emptyset_i = \sum_{i \in T}(|T-1|)!\,(n-|T|)\,!\,[\text{v}(T) - \text{v}(T-i)]/n!$, where T denotes an information sharing coalition, $|T|$ is the size of T, n is the total number of players and the sum extends over all coalitions T not containing player i, The formula can be interpreted as follows: imagine the coalition being formed one player at a time, with each player demanding their contribution $[\text{v}(T) - \text{v}(T-i)]$as a fair compensation, and then for each player take the average of this contribution over the possible permutations in which the coalition can be formed.

To truly combine the real world with theorem, we adopt the concept of Shapley value, yet with Banzhaf power index. The Banzhaf measure (Penrose 1946; Banzhaf 1965), originally designed for changing an outcome of a vote where voting rights are not necessarily equally divided among the voters, is the probability that a party is critical for a coalition, that its desertion can turn winning coalitions into losing ones. That is, in real world, some strategic behaviors could influence the formation of some coalitions; therefore, through the concept we can block some infeasible coalitions in the business models.

In our paper, we are going to adopt the concept of the Banzhaf measure as power index to weight winning coalitions, defined by enough quota to win. To properly distribute allocation of cost savings among members in different feasible coalitions, we follow the procedures below:

Step 1: According to the definition of O2O business models, platform would always play the role of one of critical players. We try to block some infeasible coalitions where the platform does not involve in. Then there are seven feasible coalitions: {(PL)MR}, {(PM)LR}, {(PR)ML}, {(PML)R}, {(PLR)M}, {(PMR)L}, {(PMLR)}.

Step 2: After blocking some infeasible coalitions, we need to determine quota, the minimum number to become winning coalitions. We assume min{v(PM), v(PL), v(PR)} the minimum allocation of cost savings as quota, which stands for entry barrier of O2O model. That is, with the involvement of platform in a supply chain, we can at least gain these cost savings. If the characteristic function is larger than min{v(PM), v(PL), v(PR)}, we regard it as winning solution. Then we can find that all the feasible coalitions are winning coalitions:

Step 3: We now can start to identify the critical players in whole winning coalitions. In each of the winning coalitions, there would be critical members, which provide the required allocation of cost savings for the coalition, and unnecessary members. Now we can find out critical players (underlined) below. The set winning coalitions with critical players underlined is {{(PL)MR}, {(PM)LR}, {(PR)LM}, {(PML)R}, {(PLR)M}, {(PMR)L}, {(PLMR)}}

Obviously, the coalition is able to provide the required production, even when one of these unnecessary members goes out of the winning coalition. However, when one necessary member leaves, the winning coalition becomes insufficient. The player P is necessary for whole seven winning coalitions, L is necessary for one winning coalitions, M also for one winning coalitions, R for one winning coalitions. Therefore, P is necessary in 0.7 of the total cases (10 = 7+1+1+1, so 7/10= 0.7), L in 0.1, M in 0.1, and R in 0.1. Since the Banzhaf index is derived by simply counting, we can find that there are 10 total swing players, the coalitions in which participate would win, or would lose, and the power is divided as: P = 7/10, L = 1/10, M = 1/10, R = 1/10.

Obviously, platform dominates the weight of distribution of cost allocation. As the main source of cost allocation, P is definitely the critical player of the game, or it would be meaningless to construct a platform as well as adopt O2O model. The importance of platform also corresponds to that, in our O2O model, platform is the coordinator of information flow, and the cost of P would definitely decrease by a wider margin than other players' cost due to its larger base of fixed cost.

After calculating the Banzahf power index, next, we will compute one of the most important part of Shapley value, marginal contributions of individual players (MC) to coalitional scheme.

Now, we can use the results from Banzhaf measure to calculate the allocated cost saving to the supply chain member *i* : P, L, M, R completely.

$$\emptyset_p = 7/10\ \{[\mathrm{v(P)} - \mathrm{v}(\emptyset)] + [\mathrm{v(PL)} - \mathrm{v(L)}] + [\mathrm{v(PM)} - \mathrm{v(M)}] + [\mathrm{v(PR)} - \mathrm{v(R)}] + [\mathrm{v(PML)} - \mathrm{v(ML)}] + [\mathrm{v(PLR)} - \mathrm{v(LR)}] + [\mathrm{v(PMR)} - \mathrm{v(MR)}] + [\mathrm{v(PMLR)} - \mathrm{v(MLR)}]\}$$

$$\emptyset_l = 1/10\{[\mathrm{v(L)} - \mathrm{v}(\emptyset)] + [\mathrm{v(PL)} - \mathrm{v(P)}] + [\mathrm{v(PML)} - \mathrm{v(PM)}] + [\mathrm{v(PLR)} - \mathrm{v(PR)}] + [\mathrm{v(PMLR)} - \mathrm{v(PMR)}]\}$$

$$\emptyset_m = 1/10\{[\mathrm{v(M)} - \mathrm{v}(\emptyset)] + [\mathrm{v(PM)} - \mathrm{v(P)}] + [\mathrm{v(PML)} - \mathrm{v(PL)}] + [\mathrm{v(PMR)} - \mathrm{v(PR)}] + [\mathrm{v(PMLR)} - \mathrm{v(PLR)}]\}$$

$$\emptyset_r = 1/10\{[\mathrm{v(R)} - \mathrm{v}(\emptyset)] + [\mathrm{v(PR)} - \mathrm{v(P)}] + [\mathrm{v(PLR)} - \mathrm{v(PL)}] + [\mathrm{v(PMR)} - \mathrm{v(PM)}] + [\mathrm{v(PMLR)} - \mathrm{v(PML)}]\}.$$

4. CONCLUSION

Through comparing the results of cost saving among different coalitional schemes in the O2O system, the calculated result gives these coalitions clear and definite answer that it can obtain more profits when collaboration with others than join market by itself. We show empirically that our proposed method of distributing cost and coalitional scheme better than the original state of supply chain and the traditional method used in practice, as these typically used method ignore the benefits of information sharing among players. The proposed methods are computationally efficient in cost savings.

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