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Summer 5-27-2016

An Inventory Decision Model of BOPS Retailing Considering Cross-selling

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An Inventory Decision Model of BOPS Retailing Considering Cross-selling

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Abstract: Omnichannel retailing has been getting more and more attention as people's buying habits become more diverse. BOPS (Buy-on-line, Pick-up-in store) is an important pattern of Omnichannel retailing which has significant impacts on a cross-selling effect and inventory decisions. This paper explores this implementation with cross-selling from a perspective of inventory management by developing and analyzing a mathematical model based on EOQ model. After series of numerical experiments, we found that firms in a perfectly competitive market have motivations to launch BOPS services in most cases, especially when the supply chain structure is centralized. Furthermore, in a decentralized supply chain, if the manufacturer bears the inventory costs generated in B&M stores according to the proportion of BOPS sales when the inventory capacity is not big enough, the retailer can shift a part of costs to the manufacturer by deliberately making biased inventory decisions, and this cost shifting may damage the manufacturer's motivation to implement BOPS where the cross-selling effect is powerful enough.

Keywords: omnichannel retailing; BOPS; cross-selling; EOQ

1. INTRODUCTION

With the development of Internet-based, especially Mobile-Internet-based E-commerce, omnichannel retailing becomes more and more widespread [1, 2]. Omnichannel retailing means that retailers take integration strategies for online channels and traditional brick-and-mortar (B&M) channels to give consumers a seamless shopping experience[3-5], and the "buy-online, pick-up-in-store" (BOPS) project is one of the ways to accomplish it. With a BOPS project, consumers can view, choose and purchase the products they need online, and then pick up them at the nearest stores of the retailer whenever they are free [6].

BOPS actually makes two differences. On one hand, the pressure from inventory of the B&M stores is higher, which implies higher inventory cost; on the other hand, more consumers come to B&M stores, which usually means greater consumption potential---people who come to the stores for picking up products they bought online may casually buy something else, and such phenomena are generally called cross-selling [7, 8]. These two changes have totally opposite impacts on profits of the firms, and it is necessary to build a mathematic model to describe the issue and explore the details and features of it. We try to answer these questions that 1) under what conditions can the BOPS service be implemented? 2) How would the firms' optimal inventory decisions adapt to the changes of external conditions? 3) What are their profits under the optimal decisions?

Reviewing the literature, *omnichannel retailing* was first proposed by Darrell Rigby in *Harvard Business Review* at 2011 where he described the omnichannel retailing as a trend which retailers must follow to survive the revolution of e-commerce[1]. Then some scholars joined the discussion---David Bell posted several commentaries in *MIT Sloan Management Review* to discuss the importance of omnichannel retailing mainly from the perspectives of the shortages of pure e-commerce and why online retailers need to develop offline channels[2, 3]; Erik Brynjolfsson et al. also thought that omnichannel retailing is an inevitable trend[4]; James

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Rowell pointed out that an integrated omnichannel retailing is the most competitive one among all existent retailing patterns[5].

Besides these commentaries, some empirical studies were also conducted---David Bell et al. made comparison of three patterns of retailing by analyzing data from a fashion eyewear retailer WarbyParker.com, and found that consumers would take their chances to choose appropriate channels according to their requirements of product information[8]; Santiago Gallino et al. studied two different patterns of omnichannel retailing in two researches, one of which revealed that Ship-To-Store (STS) can significantly increase sales dispersion and, however, translate into higher inventories and operational costs[7]. Another research of them proposed the concept of BOPS and found that BOPS can lead to cross-selling effect and channel-shift effect[6]. Stephen Mahar et al. were also interested in BOPS and, moreover, the return demand of consumers, they developed a mathematical model to find that not all retail stores should be offering in-store pickups and/or returns, and optimizing the set of pickup and return locations may reduce system cost over baseline marketing policies[9].

From all researches mentioned above, we can see that previous researchers focused on demonstrating the necessity and studying the different impacts of the omnichannel retailing in different patterns, including BOPS, and most of them went in empirical ways. Until now, few scholars have tried to analyze the retailer's decision making problems as they have being placed in an omnichannel retailing environment, which we think are worth researching as the omnichannel retailing is becoming the ordinary.

In this paper, we present an inventory decision model to characterize a basic situation of a BOPS project for a certain product, considering cross-selling on another. Our inventory model is based on the well-known Economic-Order-Quantity (EOQ) model[10], and two kinds of supply chain structure are considered, i.e. centralization and decentralization, the former of which means that a supplier or a big retailer (collectively referred to as an omnichannel retailer hereinafter) takes control of both online and offline channels and makes decisions for maximizing the overall profit of supply chain; the latter means that the manufacturer has his own online channel while the retailer controls B&M stores, and both of them run for their own profits. This schema of model construction is based on the experiences of previous researches in the field of dual-channel or hybrid channels supply chain[11, 12].

By series of numerical experiments, we found that 1) whether omnichannel retailers in centralized supply chain or manufacturers and retailers in decentralized one have motivations to launch BOPS services in most cases as the BOPS is getting more and more demand, and in addition, omnichannel retailers are more adaptable; 2) in a decentralized supply chain, if the manufacturer bears the inventory costs of the certain product generated in B&M stores according to the proportion of BOPS sales while the storehouse's capacity is not big enough, the retailer can shift a part of costs to the manufacturer by deliberately biased inventory decision making, and this costs shifting could damage the manufacturer's initiative of launching BOPS project if the cross-selling effect is powerful enough.

The rest of this paper is organized as follows: Section 2 develops the model and presents the solving method. Section 3 analyzes the model by numerical experiments. Section 4 concludes the paper.

2. MODEL CONSTRUCTION AND SOLUTION

2.1 Assumptions

We discuss a situation that two products are sold through two distribution channels in a perfectly competitive market. As presents in Figure 1, Product 1 is sold in both two channels and faces three types of consumers---traditional offline consumers only buy products in the B&M store, traditional online consumers buy products online and their orders are sent out from online channel directly, BOPS consumers purchase online

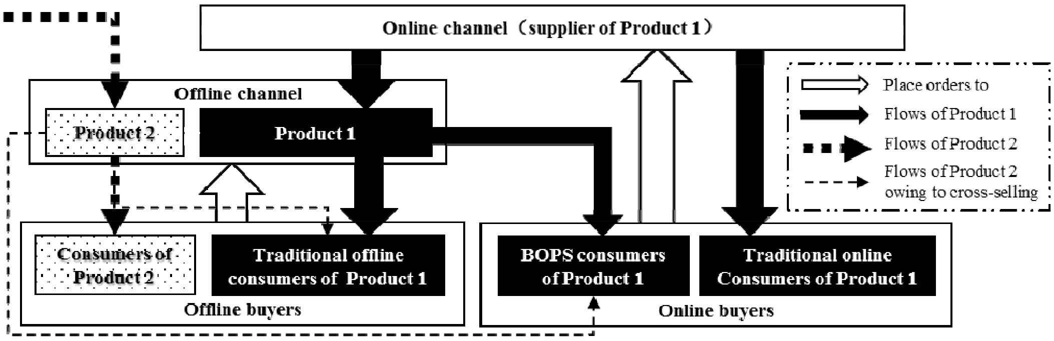

Figure 1. The case of BOPS project considering cross-selling

but pick up their products in the B&M store. The supplier of Product 1 is who controls the online channel. However, Product 2 is sold in the B&M store only as its source of supply is ignored, and besides its inherent demand in the market, the consumers coming to the store for Product 1 (buying or just picking up) may bring unexpected demand.

We suppose that the demand rates of both products are predictable and constant, and all lead-times are supposed to be zero as our model is developed based on EOQ model. For Product 1, being out of stock is obviously not allowed in the B&M store if BOPS project is implemented, so a standard EOQ model is applicable. As for Product 2, planned backorders are permitted and the penalty cost for one unit backordered during one time-unit is assumed to be constant. Besides, The B&M store have one storehouse with limited capacity for these two products.

Because of the perfect competition, the prices of both products are exogenous, and Product 1’s prices in different distribution channel are the same. When the supply chain is decentralized, of course the revenue from the pieces of Product 1 picked up by BOPS consumers belongs to the manufacturer, so the manufacturer should pay the resulting inventory cost to the retailer who actually manages the inventory of Product 1 in the B&M store; As for other pieces of Product 1 that bought by traditional offline consumers, the retailer should pay an exogenous wholesale price to the manufacturer for them and bear the inventory cost generated by them. Moreover, except inventory cost, all other costs are assumed to be zero.

2.2 Application of EOQ models

For the demand structure, let a_1 and a_2 denote the basic demand rates of Product 1 and 2 respectively; $D_{1r} = \theta a_1$, $D_{1b} = (1-\theta)\beta a_1$, $D_{1m} = (1-\theta)(1-\beta)a_1$ denote the demand rates of Product 1’s traditional offline consumers, BOPS consumers, and traditional online consumers; $D_2 = a_2 + \eta(D_{1r} + D_{1b})$ denotes the actual demand rate of product 2 after considering the cross-selling effect, where η is the measurement of the efficacy of cross-selling effect.

As for the inventory issue, given $i = 1, 2$ representing the two products, q_i denotes the order quantity for Product i, s_i denotes the maximum stock level of Product i, v_i denotes the inventory space each single Product i occupies, k_i denotes the fixed ordering cost for each order of Product i, h_i denotes the holding cost for each single Product i in unit time, and b_i denotes the backorder cost for each single Product i in unit time. And all parameters above are supposed to be non-negative.

If BOPS project is implemented on Product 1, according to the standard EOQ model, $s_1 = q_1$ always holds in optimal strategies, and the inventory cost in unit time for Product 1 is

$$C_1(s_1) = \frac{k_1(D_{1r} + D_{1b})}{s_1} + \frac{h_1 s_1}{2}. \qquad (1)$$

The EOQ model with planned backorders is applicable to Product 2, and the inventory cost is

$$C_2(s_2,q_2)=\frac{k_2D_2}{q_2}+\frac{h_2s_2^2}{2q_2}+\frac{b_2(s_2-q_2)^2}{2q_2}. \quad (2)$$

However, if no BOPS project is implemented, Model (2) is also suitable for Product 1, i.e.

$$C_1'(s_1,q_1)=\frac{k_1(D_{1r}+D_{1b})}{q_1}+\frac{h_1s_1^2}{2q_1}+\frac{b_1(s_1-q_1)^2}{2q_1}. \quad (3)$$

In order to be more realistically, all decision variables, i.e. s_1, q_1, s_2 and q_2, are required to be integers.

2.3 Decision models and profits

In a centralized supply chain, the omnichannel retailer makes inventory decisions to maximize its profit. Since the prices of both products are exogenous (denoted by p_1 and p_2 separately) and all other costs are assumed to be zero, maximizing the profit is equivalent to minimizing the inventory cost. Hence the model of the omnichannel retailer's decision is

$$\begin{aligned}\min\quad & C_c(s_1,s_2,q_2)=C_1(s_1)+C_2(s_2,q_2)\\ s.t.\quad & v_1s_1+v_2s_2\le V\\ & s_1,s_2,q_2\in N\end{aligned}. \quad (4)$$

Note that V denotes the storage capacity of the B&M store and the first constraint insures that the inventory space is enough even when these two products' stocks reach their peaks at the same time. However, $C_1(s_1)$ should be replaced with $C_1'(s_1,q_1)$ when no BOPS project has been launched, and accordingly, q_1 need to be added into the decisions, the same to following models.

In a decentralized supply chain, since the manufacturer bears a part of Product 1's inventory cost, the retailer's decision model turns into

$$\begin{aligned}\min\quad & C_d(s_1,s_2,q_2)=\left(\frac{D_{1r}}{D_{1r}+D_{1b}}\right)C_1(s_1)+C_2(s_2,q_2)\\ s.t.\quad & v_1s_1+v_2s_2\le V\\ & s_1,s_2,q_2\in N\end{aligned}. \quad (5)$$

Regardless of the details of decision model, we use (s_1^*,s_2^*,q_2^*) to denote the optimal decision. Therefore, in the centralized supply chain, the omnichannel retailer's profit under optimal decision is

$$\Pi_c^*=p_1(D_{1r}+D_{1b}+D_{1m})+p_2D_2-C_c(s_1^*,s_2^*,q_2^*). \quad (6)$$

While in the decentralized supply chain, the manufacturer and the retailer respectively get profits as following (wp_1 denotes the whole price of Product 1 where $w\in[0,1]$):

$$\Pi_m^*=wp_1D_{1r}+p_1(D_{1b}+D_{1m})-\left(\frac{D_{1b}}{D_{1r}+D_{1b}}\right)C_1(s_1^*), \quad (7)$$

$$\Pi_r^*=(1-w)p_1D_{1r}+p_2D_2-C_d(s_1^*,s_2^*,q_2^*). \quad (8)$$

2.4 Solutions

How to get (s_1^*,s_2^*,q_2^*) is the remaining question. Due to the fractional objective functions and the integer constraints, it is hard to figure out analytical solutions, so we take the second choice and provide a method to find out the numerical solutions of the decision models above. It is easy to observe that Model (4) and (5) share the same structure, so the following method is applicable to both of them.

Firstly, there is no constraint on q_2 except being integer, so if we ignore this constraint, the analytical optimal solution of q_2 can be easily obtained as the objective function is a convex function of q_2, i.e.

$$\tilde{q}_2^*(s_2) = \sqrt{\frac{b_2 + h_2}{b_2} s_2^2 + \frac{2k_2 D_2}{b_2}} \,. \tag{9}$$

And then considering the integer constraint, the optimal solution of q_2 must be the maximum integer which is not greater than $\tilde{q}_2^*(s_2)$ or the minimum integer which is not less than that as long as the value of s_2 has been given. We use $q_2^*(s_2)$ to denote the optimal integral value of q_2.

Secondly, when all constraints are ignored, the analytical optimal solution of s_1 is

$$\tilde{s}_1^* = \sqrt{\frac{2k_1(D_{1r} + D_{1b})}{h_1}} \,. \tag{10}$$

Similarly, we can find the optimal $\overline{s}_1^*$ around $\tilde{s}_1^*$ considering the integer constraint. However, different from q_2, the value of s_1 must follow the store capacity constraint, so given any s_2, the optimal solution of s_1 should be

$$s_1^*(s_2) = \min\left\{\overline{s}_1^*, \left\lfloor \frac{V - v_2 s_2}{v_1} \right\rfloor\right\}. \tag{11}$$

In summary, given any $s_2 \in N \cap [0, V/v_2]$, it is easy to find the corresponding optimal solution of q_2 and s_1, i.e. $q_2^*(s_2)$ and $s_1^*(s_2)$, and then figure out the corresponding objective function value. When every possible value of s_2 has been tried, we can find the optimal one (denoted by s_1^*). Then we get the optimal solution of the decision model, i.e. $\left(s_1^*, s_2^*(s_1^*), q_2^*(s_1^*)\right)$.

Similar method can be taken to solve the decision models without BOPS.

3. ANALYSIS

To confirm the validity of the models and to study their features, we conducted a series of numerical experiments and got some interesting conclusions. Default values of all parameters are showed in Table 1, and they were selected to reflect the reality as accurately as possible, and because we don't take the differences between Product 1 and Product 2 into consideration, most characteristics of them are set to be the same.

Table 1. Basic values of all parameters

	$p_{1,2}$	w	$a_{1,2}$	θ	β	η	$k_{1,2}$	$h_{1,2}$	$b_{1,2}$	$v_{1,2}$	V
Product 1	1	0.5	100	0.5	0.5	0.1	10	1	5	1	70
Product 2	1	--	100	--	--		10	1	5	1	

3.1 Centralized supply chain

Let Π_c^* (Π_{cnb}^*) donates the optimal profit of the omnichannel retailer with (without) BOPS, Figure 2 shows the comparison of situations with and without BOPS when $\eta = 0$ (no cross-selling effect). Region A in Figure 2-b means the omnichannel retailer can get more profit by implementing BOPS and Region B means the contrary. We can see that even without cross-selling effect, implementing BOPS is the better choice in most cases, except when traditional offline consumers make up a large majority of the demand of Product 1, or BOPS consumers of Product 1 are quite few.

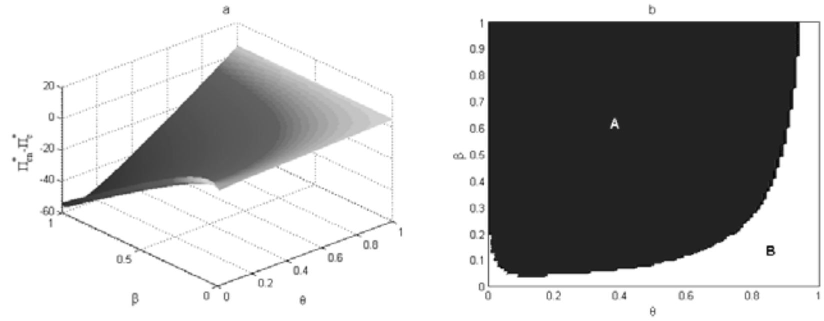

Figure 2. Comparison of profit with and without BOPS in centralized supply chain (*η*=0)

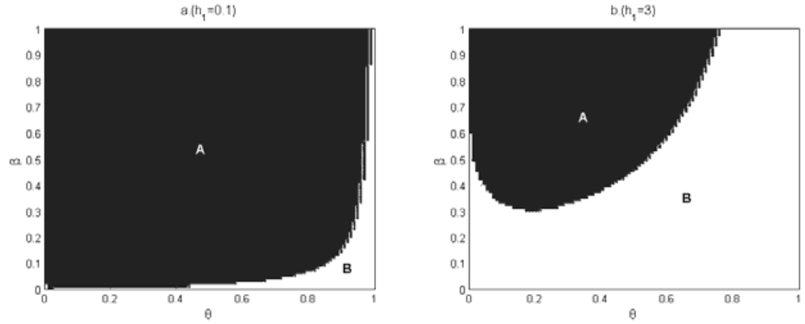

Figure 3. Incentive to implement BOPS in centralized supply chain (*η*=0)

To check the robustness of this conclusion, Figure 3 shows the results when $h_1 = 0.1$ and $h_1 = 3$, respectively represent the situations when Product 1's holding cost is comparatively low and high. The result shows that Region A shrinks when h_1 goes up, that is to say the omnichannel retailer's motivation to implement BOPS can be discouraged by high holding cost. However, considering the price of Product 1 in this experiment (i.e. $p_1 = 1$), $h_1 = 1$ is relatively high comparing to most cases of reality.

For impacts of the demand structure, with our assumptions of the centralized supply chain, the BOPS consumers and the traditional offline consumers have the same effects on cost and profit, thus we put $\left(\theta + \beta - \theta\beta\right)$ as a key parameter of demand structure which denotes the ratio of demands that go to the B&M store for Product 1. From Figure 4, the more consumers of Product 1 come to the store, the higher inventory cost should be covered, but the profit is not always lower---as long as the cross-selling effect is powerful enough, the profit may rises with the increasing of consumers coming to the store. As a result, only when the cross-selling effect rises to an extent, the omnichannel retailer can benefit from encouraging consumers of Product 1 to visit the B&M store.

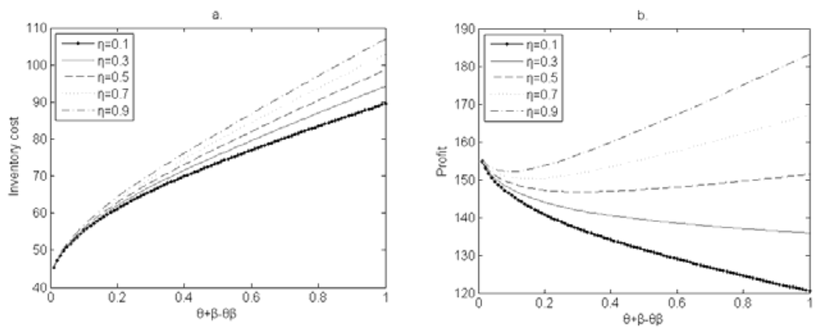

Figure 4. Influences of demand structure on cost and profit in centralized supply chain with BOPS

3.2 Decentralized supply chain

Firstly, we focus on motivations of the manufacturer and the retailer to implement BOPS. Figure 5-a shows the results when $\eta = 0$, where Region (A+B_r) and Region (A+B_m) respectively mean the retailer and manufacturer have incentives to implement BOPS. However, a BOPS project can be launched only when both of them have incentives (Region A). Figure 5-b, c, d show the results when η takes different values.

The results in Figure 5 indicate that the retailer's inclination to implement BOPS will cover more situations when cross-selling effect becomes stronger, which need not go into detail. As for the manufacturer, generally considering, the cross-selling effect should not impact the manufacturer at all, but Figure 5 shows that an extremely high η will damage the manufacturer's initiative. To explain this phenomenon, we can find some clues in Figure 6.

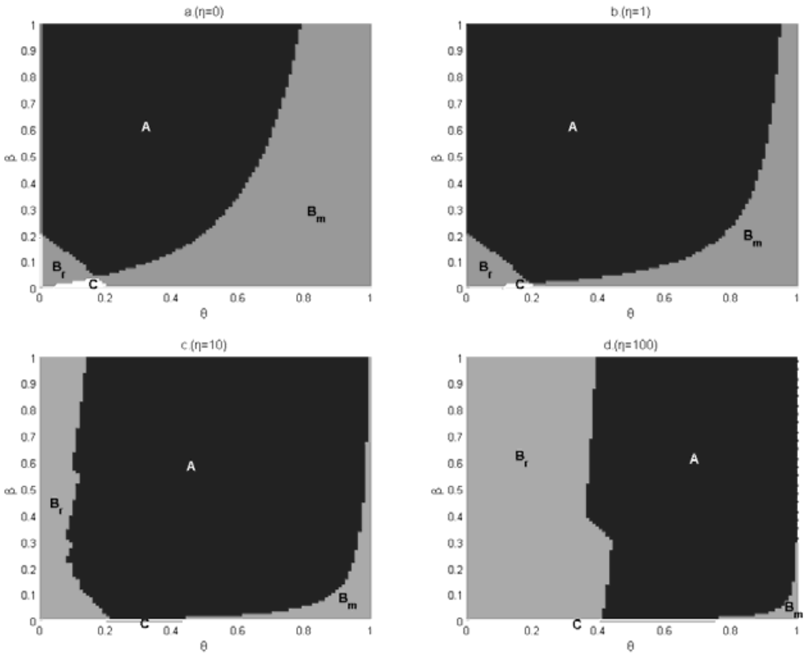

Figure 5. Incentive to implement BOPS in decentralized supply chain

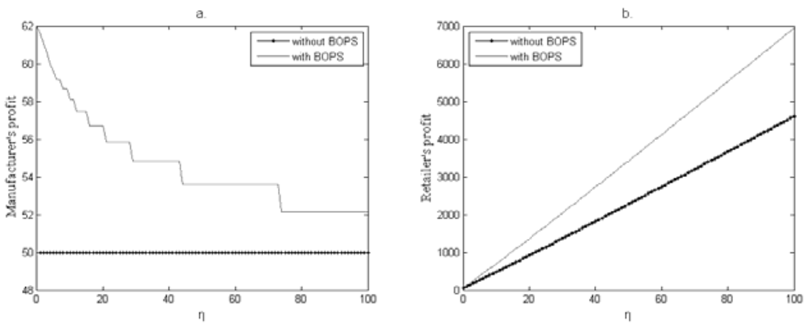

Figure 6. Influences of cross-selling effect on profits in decentralized supply chain

From Figure 6-a, we can see that the manufacturer's profit will drop down when cross-selling effect becomes stronger as long as a BOPS project has been launched. Considering that the manufacturer's revenue must be constant, changes do certainly come from the inventory cost of Product 1 for BOPS. By analyzing changes of retailer's optimal inventory decisions, we confirmed that, as cross-selling effect becomes stronger, the retailer will deliberately raise the capitation inventory cost of each piece of Product 1 to minimize the part of inventory costs he bears, and at the same time the other part of costs that the manufacturer bears increase. Because it seems like the retailer shifts some costs to the manufacturer by the inventory cost sharing mechanism in a BOPS project, we name this phenomenon as **cost-shifting effect**. As Figure 5 shows, as long as the cross-selling effect is powerful enough, the cost-shifting effect may damage the manufacturer's motivation to implement BOPS, however these critical values of η in this experiment are quite high comparing to most situations in reality.

4. CONCLUSIONS

In this paper, we present a model to describe and analyze the inventory decision problem in a supply chain with online and offline distribution channels implementing BOPS, considering the cross-selling effect and a storage capacity constraint. We conducted a series of numerical experiments to verify the validity of this model and got some interesting conclusions. No matter the supply chain is centralized or decentralized, the sellers have incentives to launch a BOPS project in most cases as the BOPS is getting more and more demand, however a omnichannel retailer who owns both online and offline channels is more adaptable. In a decentralized supply chain, if the manufacturer who owns the online channel bears the inventory costs generated by products for BOPS in the B&M store while the storehouse's capacity is limited, the retailer who owns the B&M store can shift a part of costs to the manufacturer by deliberately biased inventory decision making, and such cost-shifting effect may damage the manufacturer's incentive to implement BOPS if the cross-selling effect is strong enough.

In the following researches, stochastic demand may be considered, and the prices of the related products can be assumed endogenous to build a pricing and inventory decision model.

ACKNOWLEDGEMENT

This research was partially supported by the National Natural Science Foundation of China (71271219, 71210003, 71431006), by the Two-oriented Society Research Center of Central South University 985 Project under Grant No.ZNLX1102, by Innovation-driven program of Central South University (2015CX010), by Mobile E-business Collaborative Innovation Center of Hunan Province.

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