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Stockout management: how does customers’ brand and store loyalty influence supply chain performance?

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ABSTRACT
Customers who experience stockout of the preferred product will choose backlogging, brand switching, store switching, or not buy at all (lost sales). Assuming a two-stage supply chain of a manufacturer and N retailers that sell M brands, we extend the newsvendor model to include these four types of customers’ responses to stockout, and then, we numerically examine how consumer behavior in response to product stockout influences a retailer’s order size, expected profit of a manufacturer and a retailer, and the negative effect due to double marginalization.

KEYWORDS: Newsvendor model, Product stockout, Double marginalization, Consumer behavior

INTRODUCTION
A mismatch between supply and demand is unavoidable owing to uncertainties in demand information and supply chain operations. Consequently, lost sales due to product stockout decrease a firm’s revenue in the short run and undermine a firm’s reputation and their customers’ loyalty in the long run. In fact, retail practitioners regard lost sales as one of most serious concerns. For example, Seven-Eleven Japan, the largest convenience store chain in Japan and one of the Triple-A supply chain companies as identified by Lee et al. (1997), insists that product stockout on store shelves must be avoided because when products that customers come to the store to buy are unavailable, it destroys their store loyalty (Tanaka 2013). At the same time, if a customer faces stockout of a preferred product but has high preference for this product, he or she may choose backlogging (i.e., asking a store to deliver the unavailable product later) or store switching (i.e., searching for the preferred product at another store). Even if the product preference is not high, if the customer with unmet demand has strong loyalty to the store, he or she may choose brand switching (i.e., picking an other product that is similar to the preferred but unavailable product). In other words, if a customer with strong brand or store loyalty faces product stockout, he or she may select backlogging, brand switching, or store switching instead of simply quitting the purchase (i.e., lost sales). We describe this behavior, which is observed often in daily shopping, as customers’ active response to stockout.

Many marketing research papers have addressed the effect of product unavailability on consumers. Emmelhainz et al. (1991a) empirically studied grocery store customers’ responses to product stockouts. The scholars found that customers with strong store loyalty tend to choose store switching or delaying the purchase and that customers who realize the risk of using unknown brands and urgency of the usage are likely to substitute a different brand or different size. Pizzi
and Scarpi (2013) used an experimental study assuming the purchase of laptop computers via an online retailer to show that the negative effect of product stockout can be mitigated when customers are informed, in which the responsibility and justification of unavailability are related to the firm, before they decide to purchase or order. Diels et al. (2013) used the framework of context theory and phantom theory to show customers' preference shift and substitution patterns owing to product stockout. Ku et al. (2014) studied consumer reaction to stockout of a preferred product by investigating how stockout as a social cure affects consumers' consideration of “differentiation” and “assimilation” and how the cause of the stockout, whether demand-based or supply-based, influences the preference for the product that they initially want.

Researchers in operations management have also studied the impact of stockout from various viewpoints of a firm's operations. For example, based on in-store interviews with grocery store shoppers, Emmelhainz et al. (1991b) studied the logistics and marketing impacts of product stockout for the manufacturer and the retailer and then presented the differences in the impacts between the two firms. Anderson et al. (2006) conducted a field study of mail-order catalog shopping to measure the short- and long-run impacts of stockout on demand and analyzed the effectiveness of five responses that a firm offers customers to mitigate the cost of the stockout. Zinn and Liu (2008) estimated the actual response to stockout compared with the intended response that most studies on stockout have addressed and examined the factors that influence consumers’ responses to stockout. Abad (2008) investigated the pricing and lot-sizing decisions, including the costs of lost sales, backorders, and shortage cost. Cai et al. (2011) used a game theoretic model of price and order decisions between a seller and a buyer to discuss how pricing and ordering interact when a certain portion of unmet demand is assumed to be partial lost sales.

Meanwhile, supply chain contracts have been the main research theme in modern supply chain research. As long as one firm in a supply chain makes a profit-maximization decision without considering the other supply chain members’ profits, the total benefits of the supply chain will be lower than the global optimal level. This phenomenon is called double marginalization. Supply chain contracts are a strategic method by which a supply chain that originally reaches only a local optimum owing to double marginalization can achieve the performance of the global optimum by adequately sharing risks and/or benefits among the members. For example, in a buyback contract, the most frequently adopted supply chain contract, a supplier sells products at unit wholesale price $w$ to a buyer and buys back unsold items at a price lower than $w$ (Cachon 2003). An adequately arranged buyback contract can generate a win-win situation for a supplier and a buyer: Each firm can gain more profit with the contract than without it, and the total profit of the entire system can reach the global optimal level. Many researchers consider a buyback contract from various managerial perspectives. Recent studies that have considered a buyback contract and a newsvendor approach in a two-stage supply chain include those by Yuyue et al. (2008), Katok and Wu (2009), Kurtuluş et al. (2012), and Wu (2013). Furthermore, Cachon (1998, 2003) provided a detailed explanation of supply chain contracts and double marginalization.

This study investigates how customers’ active response to product stockout influences the order decision, profit of a retailer and a manufacturer, and negative effect owing to double marginalization, assuming a two-stage supply chain of a manufacturer and $N$ homogeneous retailers that sell $M$ exchangeable products including the manufacturer's product. Based on numerical analyses, we propose marketing suggestions, such as the appropriate development of store and/or brand loyalty, and discuss how adequate management of customers’ responses to stockout will improve the store’s profitability.

Specifically, assuming that some customers who experience stockout of the product that they want at a store choose backlogging (BB), brand switching (BS), or store switching (SS) in addition to
quitting purchasing (i.e., lost sales), this study answers the following questions:

Research Question 1

What is the difference in optimal order sizes and profits between a traditional newsvendor model that considers only lost sales and the proposed model that includes backlogging, brand switching, and store switching in addition to lost sales as customers’ active responses to stockout of the preferred product?

Research Question 2

How much does the performance of the non-integrated model reach the global optimal level that the integrated model attains if some portion of customers who experience stockout choose backlogging, brand switching, or store switching instead of lost sales?

Research Question 3

Can consumer behavior such as customers’ active responses to stockout substitute for a supply chain contract as a tool for attaining the global optimum? In other words, can a certain number of customers who choose backlogging, brand switching, or store switching replace a buyback contract as a tool for resolving double marginalization?

The remainder of this article is organized as follows. Section 2 explains the assumptions and model formulation. Section 3 numerically analyzes the models and presents answers to the aforementioned research questions. Section 4 proposes several managerial implications. Finally, Section 5 concludes this study and suggests future research directions.

MODEL

Supply Chain Structure

We assume a two-stage supply chain of a manufacturer and $N$ homogeneous retailers (Retailers $1 \sim N$) at which $M$ exchangeable products (Brands $1 \sim M$) are sold. We set the retailer of interest and the product that the manufacturer produces as index 1 (i.e., $i = 1$ for the retailer of interest and $j = 1$ for the manufacturer’s brand where $i \in \{1, \ldots, N\}$ and $j \in \{1, \ldots, M\}$). All the symbols are listed in Table 1. The manufacturer applies an MTO-type production system in which products are produced according to the order from the retailer, and the retailer uses an MTS-type sales system in which the retailer has to bear the cost due to a mismatch between the supply and the customer demand. We assume that the capacity of the manufacturer is large enough to fulfill any order from the retailer, including an additional order of backlogged items, without delay.
Table 1: Notations and Symbols

<table>
<thead>
<tr>
<th>Notations and Symbols</th>
<th>Description</th>
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<tbody>
<tr>
<td>(\alpha, \beta, \gamma)</td>
<td>Portions of customers experiencing stockout who will choose BB, BS, and SS, respectively. (\alpha, \beta, \gamma \geq 0) and (0 \leq \alpha + \beta + \gamma &lt; 1)</td>
</tr>
<tr>
<td>(p, w, c)</td>
<td>The retail price, wholesale price, and unit production cost, respectively</td>
</tr>
<tr>
<td>(k_B)</td>
<td>Additional cost that a retailer pays for a backlogged item, (k_B \geq 0)</td>
</tr>
<tr>
<td>(M) and (N)</td>
<td>The number of brands and stores, respectively</td>
</tr>
<tr>
<td>(x) and (f(x))</td>
<td>Random demand following the pdf function, (f(x)). (x \geq 0).</td>
</tr>
<tr>
<td>(F(x))</td>
<td>The cdf function of (f(x))</td>
</tr>
<tr>
<td>(b_l)</td>
<td>Money that the manufacturer pays for unsold products</td>
</tr>
<tr>
<td>(q)</td>
<td>A retailer’s order size</td>
</tr>
<tr>
<td>(\pi_R, \pi_M, \pi_I)</td>
<td>The profit of the retailer, the manufacturer, and the integrated supply chain, respectively</td>
</tr>
<tr>
<td>(\mu) and (\sigma)</td>
<td>Mean and standard deviation of the random demand, respectively</td>
</tr>
<tr>
<td><strong>Subscripts</strong></td>
<td></td>
</tr>
<tr>
<td>(R, M, I)</td>
<td>The retailer, the manufacturer, and the integrated model, respectively</td>
</tr>
<tr>
<td><strong>PL and SR</strong></td>
<td>The perfect lost sales (PL) and stockout response (SR) model, respectively</td>
</tr>
<tr>
<td><strong>Superscripts</strong></td>
<td></td>
</tr>
<tr>
<td>(0) and *</td>
<td>The optimum value of the integrated model and non-integrated model, respectively</td>
</tr>
</tbody>
</table>

Meanwhile, in addition to Brand 1 that the manufacturer of interest produces, each retailer sells \(M - 1\) other brands that are similar and exchangeable with Brand 1. Therefore, if a customer experiencing stockout chooses brand switching, this customer can buy a product from among the \(M - 1\) similar and available brands. We assume that the number of \(M\) is large enough so that once a customer with unmet demand chooses brand switching, he or she will be able to buy a similar product. Similarly, we assume that the number of retailers \(N\) is large enough for a store switcher to find the product that he or she originally wants somewhere. Note that these two assumptions of large \(N\) and \(M\), which lead to the result that unmet demand will definitely be satisfied once a customer chooses either brand switching or store switching, can distinguish brand and store switching from lost sales. Figure 1 graphically explains our supply chain model with customers’ responses to product unavailability. Note that the settings represent a sort of real sales environment. For example, the setting reflects a situation in which electronic appliance retail chains sell a commoditized product, such as flat-panel TVs and tablets. Under these supply chain settings, we can define the expected profit functions of the retailer and the manufacturer as explained later.
Customer's Response to Product Stockout

This study assumes the following four customer responses after finding that a preferred product is out of stock.

**Backlogging (BL):** Some portion of the customers who experience stockout still place an order with the retailer in order to receive the item later. We set this portion as $\alpha$ ($0 \leq \alpha < 1$). In other words, $100 \times \alpha$% of all customers experiencing stockout choose backlogging. In our model, the backlogging orders, which are treated as special rush orders different from regular orders, incur an additional cost per unit $k_L$ to the retailer by the manufacturer (owing to, for example, an additional paperwork or special delivery fee). However, in our setting, the customer who chooses backlogging does not need to pay an extra charge.

**Brand switching (BS):** Our model sets brand switching as if Brand $i$ is unavailable at a store, the unsatisfied customer will buy Brand $j$ ($i \neq j$) at the same store as long as Brand $j$ is available. We set the portion of brand-switching customers who experience stockout as $\beta$. In other words, $100 \times \beta$% of all customers experiencing stockout choose brand switching. In our setting, the retailer incurs no extra charge when a customer chooses brand switching.

**Store switching (SS):** Store switching is defined as a situation in which if Brand $i$ is unavailable
at a certain store, the unsatisfied customer will go to another store to search for Brand $i$ and buy it there if it is available. In our setting, the retailer incurs no extra charge when a customer chooses store switching; in other words, any additional cost incurred due to store switching (e.g., extra transportation cost for moving one store to another) is assumed to be paid by the customer. We set the portion of customers who choose store switching as $\gamma (0 \leq \gamma < 1)$.

**Lost sales:** We define lost sales as a situation in which a customer who experiences stockout just quits purchasing. The portion of customers who choose lost sales is set as $1 - \alpha - \beta - \gamma (0 \leq 1 - \alpha - \beta - \gamma < 1)$. Lost sales are not beneficial to either a manufacturer or a retailer.

**Managerial Impact of the Customers’ Responses to Stockout**

Backlogging is clearly beneficial for a manufacturer and a retailer whereas lost sales do not lead to any financial gain for either firm (in fact, lost sales might have a negative impact on a firm in the long run, such as collapse of the firm’s reputation and goodwill). Intuitively, one may suppose that brand switching is beneficial for the store because a customer who experiences stockout remains within the same store by purchasing similar products; however, a manufacturer does not welcome brand switching because the customer will buy a competitor’s product. In contrast, one may think that store switching is profitable for a manufacturer because the customer eventually buys the manufacturer’s product. However, losing a customer owing to store switching does not lead to any profit for the retailer. The intuitive managerial impacts of backlogging (BL), brand switching (BS), store switching (SS), and lost sales are summarized in Table 2. However, as discussed later, our analysis shows that store switching is occasionally beneficial even for the retailer, whereas store switching occasionally negatively affects the manufacturer. This counterintuitive finding is one of our contributions.

<table>
<thead>
<tr>
<th></th>
<th>PORTION OF CUSTOMERS WHO EXPERIENCE STOCKOUT</th>
<th>BENEFICIAL TO THE MANUFACTURER?</th>
<th>BENEFICIAL TO THE RETAILER?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Backlogging (BL)</td>
<td>$\alpha$</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Brand switching (BS)</td>
<td>$\beta$</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Store switching (SS)</td>
<td>$\gamma$</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Lost sales</td>
<td>$1 - \alpha - \beta - \gamma$</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>

**Integrated and Non-Integrated Models**

To discuss double marginalization in a two-stage supply chain, we consider two models; *integrated* and *non-integrated* models. The non-integrated model represents a normal supply chain structure in which each firm in the supply chain individually makes its optimal decision without including the performance of the other member. In our model, a non-integrated supply chain is one in which a retailer sets its order size ($q_{R,PL}$ or $q_{R,SR}$) so as to maximize its profit, and then, the manufacturer using an MTO production system simply receives the order set by the retailer. In contrast, in an integrated system, a decision-maker makes decisions that optimize the performance of the entire supply chain. In our model, the optimal order size in the integrated system ($q_{I,PL}$ or $q_{I,SR}$) can be determined by maximizing the sum of the retailer’s and manufacturer’s profits. The solutions of the integrated and the non-integrated systems are the global and local optimums, respectively, and the local optimum is not greater than the global optimum owing to double marginalization.

**Profit Functions**
We define \( p, w, \) and \( c \) as the retail price, wholesale price, and unit product cost, respectively, and we assume that they are exogenously given. The decision variable is the retailer’s order quantity \( q \), and the random demand \( x (x \in [0, \infty)) \) is distributed following the density function of \( f(x) \). At this time, the expected profit functions are determined as follows:

**Retailer’s expected profit:**

\[
\pi_R = p \int_0^q x f(x) dx + pq \int_q^\infty f(x) dx - wq + (p - k_B - w) \alpha \int_q^\infty (x - q) f(x) dx \\
+ p \cdot \min \left[ \frac{M-1}{M} \beta \int_q^\infty (x - q) f(x) dx + \frac{N-1}{N} \gamma \int_q^\infty (x - q) f(x) dx, f_0^q (q - x) f(x) dx \right]. \tag{1}
\]

In Equation (1), the first three terms of the right-hand side express the expected profit when demand is less than the order size (i.e., \( x < q \)), the expected profit when the demand is more than the order size (i.e., \( x > q \)), and the purchasing cost when the order size is \( q \), respectively. The fourth term indicates the additional profit that occurs when some portion of the unfulfilled customers choose backlogging. It is reasonable that the retailer must pay additional cost \( (k_B) \) to deliver the backlogged items to the customer so that the unit profit of a backlogging item is assumed to be \( p - k_B - w \). The first and second terms inside the square brackets are the expected additional sales due to brand switching and store switching, respectively. Suppose that Equation (1) represents the profit that Retailer 1 obtains with the sale of Brand 1. In a brand-switching situation, a customer experiencing stockout of Brand 1 at Retailer 1 may pick up one of the competitors’ brands that are displayed near the empty slots of Brand 1 (i.e., the product of interest) within Retailer 1. Thus, we use \( \frac{M-1}{M} \) as the brand switching term, because under the assumption that all the brands are sold in a symmetric situation at a store, the number of brand switchers at Retailer 1 who finally switch to Brand 1 can be determined as the total number of customers who experience unavailability of the other \( M - 1 \) brands divided by the total number of brands (i.e., \( M \)). Therefore, the number of brand switchers who will eventually purchase unsold Brand 1 will be \( \frac{M-1}{M} \beta \int_q^\infty (x - q) f(x) dx \). We apply the same logic to the store-switching situation: The store switchers who experience unavailability of Brand 1 at the other \( N - 1 \) stores are evenly distributed over the \( N \) stores to search Brand 1 at Retailer 1. Therefore, the expected number of store switchers who come to Store 1 will be \( \frac{N-1}{N} \gamma \int_q^\infty (x - q) f(x) dx \).

Note that if \( M \) and \( N \) are large enough, one can approximate Equation (1) as Equation (2) as shown below. For tractability, hereafter Equation (2) is used as the expected profit function of the retailer.

\[
\pi_R = p \int_0^q x f(x) dx + pq \int_q^\infty f(x) dx - wq + (p - k_B - w) \alpha \int_q^\infty (x - q) f(x) dx \\
+ p \cdot \min \left[ \beta \int_q^\infty (x - q) f(x) dx + \gamma \int_q^\infty (x - q) f(x) dx, f_0^q (q - x) f(x) dx \right]. \tag{2}
\]

Meanwhile, the manufacturer’s expected profit is defined as follows:

\[
\pi_M = N \left[ (w - c)q + (w + k_B - c) \alpha \int_q^\infty (x - q) f(x) dx \right]. \tag{3}
\]

As for the manufacturer’s expected profit function, in Equation (3), the first term inside the square brackets indicates the profit owing to order \( q \) from the retailer. The second term inside the square
brackets indicates an extra order owing to backlogging. We assume that the backlogged order differs from a regular order in that the backlogged order is a special rush order and that an extra fee is paid by the retailer. Furthermore, because the number of retailers, \( N \), is fixed, hereafter, we use Equation (4) instead of Equation (3) to discuss the manufacturer’s expected profit.

\[
\pi_M = (w - c)q + (w + k_B - c)\alpha \int_q^\infty (x - q)f(x)dx.
\]  

**Perfect Lost Sales (PL) Model and Stockout Response (SR) Model**

In our setting, three types of responses to product stockout (BL, BS, and SS) are assumed to influence the profit of a firm. Therefore, to analyze the effects of these three factors, we formulate two cases. The first case considers only lost sales as the possible response of a customer with unmet demand due to unavailability. The first case is equivalent to a traditional newsvendor model, and we call this model a perfect lost sales (PL) model. The other model includes all three factors in addition to lost sales. We call this model a stockout response (SR) model. The subscripts “PL” and “SR” represent the PL and SR models, respectively.

**Global Optimum of Integrated Model**

The global optimum decision of the PL model, \( q_{I,PL}^0 \), can be obtained by solving the following integrated profit function:

\[
\pi_{I,PL} = p \int_0^q xf(x)dx + pq \int_q^\infty f(x)dx - cq.
\]  

Note that Equation (5) is a traditional newsvendor model, subscript “f” indicates the integrated model, and superscript “0” represents the optimal solution of the integrated model. The maximum profit of the integrated PL model (\( \pi_{I,PL}^0 \)) is obtained at the optimal order size of \( q_{I,PL}^0 \) as \( \pi_{I,PL}^0 = \pi_{I,PL}(q_{I,PL}^0) \). Meanwhile, the optimal order size of the integrated model of the SR model is set as \( q_{I,SR}^0 \). We can attain the global optimum decision of the integrated SR model, \( q_{I,SR}^0 \), by solving

\[
\pi_{I,SR} = p \int_0^q xf(x)dx + pq \int_q^\infty f(x)dx - cq + (p - c)\alpha \int_q^\infty (x - q)f(x)dx
+ p \cdot \min \left[ \beta \int_q^\infty (x - q)f(x)dx + \gamma \int_q^\infty (x - q)f(x)dx, \int_0^q (q - x)f(x)dx \right].
\]  

The maximum profit of the integrated SR model is then determined as \( \pi_{I,SR}^0 = \pi_{I,SR}(q_{I,SR}^0) \).

The difference between \( q_{I,SR}^0 \) and \( q_{R,SR}^0 \) represents a negative effect due to double marginalization. For example, in the buyback contract, a manufacturer pays a retailer a certain amount of buyback money \( l_b \) (0 < \( l_b \) < \( w \)) for each unsold product. This buyback money, as long as it is adequately designed, will partially shift the risk of overstocking from the retailer to the manufacturer. The retailer orders more products than without buyback money and eventually achieves better performance for the non-integrated system equivalent to the global optimum. To analyze how the customers’ response to stockout affects the order size, profits, and double marginalization, we numerically compare \( q_{I,PL}^0 \), \( q_{R,PL}^0 \), \( q_{I,SR}^0 \), and \( q_{R,SR}^0 \) to analyze the order size and \( \pi_{I,PL}^0, \pi_{R,PL}^0, \pi_{I,SR}^0, \) and \( \pi_{R,SR}^0 \) to analyze the profits. Section 3 presents several numerical examples.

**MODEL ANALYSIS**
Because analytical tractability, such as concavity and differentiability of the profit functions, is not guaranteed in our profit functions, we conduct a numerical analysis that proceeds in the following order. First, we compare the optimal order size and the corresponding maximum profit between the non-integrated and the integrated models. Next, we address how customers’ active responses to stockout impacts on the gaps in the optimal order size and the corresponding maximum profits between the integrated and the non-integrated models.

Comparison between the Non-Integrated and the Integrated Models

We arbitrarily set the parameters as $p = 30$, $w = 15$, $c = 6$, $k_B = 3$, $\mu = 250$, and $\sigma = 100$. First, Figure 2 shows the change in the order quantities and the profits in the PL model (i.e., $\alpha = 0$, $\beta = 0$, $\gamma = 0$). In Figure 2, the retailer’s profit is maximized at $q = 116$, and the corresponding maximum profit is 938.7 for the retailer and 1044.0 for the manufacturer (i.e., the total profit is 1982.7), whereas the maximum value of the integrated model is 2162.5 at $q = 154$. This implies double marginalization: The optimal order size and the corresponding total profit value of the non-integrated model are less than those of the integrated model.

Next, setting $\alpha = 0.1$, $\beta = 0.1$, and $\gamma = 0.1$, we examine how the retailer’s profits in the SR model change in terms of the order size $q$ (see Figure 3). Figure 3 shows that the maximum profit of the non-integrated SR model is 1920.3 for the retailer and 1225.6 for the manufacturer at $q = 118$ (i.e., the total profit is 3145.9), whereas that of the integrated SR model is 3148.7 at $q = 123$. The difference between the total profit of the two models at $\alpha = 0.1$, $\beta = 0.1$, and $\gamma = 0.1$ is 2.8, which represents double marginalization. The following should be noted in the numerical examples shown in Figures 2 and 3: (1) Double marginalization occurs in the non-integrated PL and SR models, (2) The optimal order size of the SR model is more than that of the PL model, and (3) The maximum profit of the SR model is more than that of the PL model.
Impact of Customers’ Active Responses to Stockout, $\alpha$, $\beta$, and $\gamma$, on Order Size and Profit

In this subsection, we study how the optimal order size and optimal profit change when the intensity of the consumers’ active responses to stockout changes. For a numerical analysis of the same, we assume that the values of $\alpha$, $\beta$, and $\gamma$ vary from 0.00 to 0.20 such that $\alpha = \beta = \gamma$. The remaining parameter values in the numerical examples in this subsection are the same as those in the previous subsection.

Figure 4 shows how the optimal order sizes of the non-integrated system ($q^*_R, SR$) and those of the integrated system ($q^*_I, SR$) change when the value of $\alpha (= \beta = \gamma)$ increases from 0.00 to 0.20. Interestingly, the curves of $q^*_R, SR$ and $q^*_I, SR$ are roughly V-shaped; in other words, the optimal order
size decreases at first and then increases from a certain value of \( \alpha \). This outcome results from the fact that when customers somehow search for an unavailable product by themselves, at first, a retailer may lose the motivation to keep much inventory (i.e., a downward curve at low \( \alpha \)), whereas when the number of customers who try to positively satisfy the unmet item is large enough, the risk of oversupply may be reduced, and thus the retailer will try to keep as much inventory as possible (i.e., an upward curve at high \( \alpha \)). Furthermore, when \( \alpha \) is small, the optimal order size of the non-integrated model is smaller than that of the integrated model; however, from a certain value of \( \alpha \) (i.e., \( \alpha \approx 0.11 \) in Figure 4), the optimal order sizes become equivalent in the integrated and non-integrated models. This means that the high level of the customers’ motivation for unmet items encourages a retailer to hold more inventory, and eventually, this leads to supply chain coordination (i.e., the non-integrated model has the same outcomes as the integrated model). This fact can be interpreted as that there is no need to apply a supply chain contract to coordinate the supply chain when a sufficient portion of customers who experience stockout try to fulfill their unmet demand by using backlogging, brand switching, or store switching.

Figure 5: Effect of the customers’ responses to stockout (\( \alpha, \beta, \) and \( \gamma \)) on the optimal profits of the retailer, manufacturer, non-integrated supply chain, and integrated supply chain

![Figure 5](image-url)

Figure 5 shows the behavior of the retailer’s maximum profit (\( \pi^*_{R, SR} \)), the corresponding manufacturer’s profit (\( \pi^*_{M, SR} \)), and the sum of these two profits (\( \pi^*_{R, SR} + \pi^*_{M, SR} \)) in the non-integrated system as well as the maximum profit of the integrated system (\( \pi^0_{I, SR} \)) when the value of \( \alpha (= \beta = \gamma) \) increases from 0.00 to 0.20. Interestingly, a gap exists between \( \pi^*_{R, SR} + \pi^*_{M, SR} \) and \( \pi^0_{I, SR} \) (i.e., double marginalization) when the value of \( \alpha (= \beta = \gamma) \) is low (i.e., roughly less than 0.06), whereas \( \pi^*_{R, SR} + \pi^*_{M, SR} \) reaches the same level as \( \pi^0_{I, SR} \) (i.e., supply chain coordination) when the value is high (i.e., roughly more than 0.06). This suggests that customer behavior, namely, choosing BB, BS, or SS, can serve as a substitute for a supply chain contract. Another interesting result is that the curve of \( \pi_{M, RS} \) is downward sloping at low \( \alpha \) whereas it is upward sloping at high \( \alpha \). This fact can be interpreted as that, at low \( \alpha \), customers’ active responses to unmet products negatively affect the retailer’s inventory decision and thus decrease the manufacturer’s profit; however, once the level of \( \alpha \) becomes high enough, the retailer is encouraged to order more inventory because products on the store shelf will be definitely bought by customers who have a strong preference.
for them. Then, high $\alpha$ leads to an increase in the manufacturer’s profit.

**DISCUSSION AND MANAGERIAL IMPLICATIONS**

The following conclusions can be drawn from the numerical examples:

**Findings from Numerical Examples**

First, assuming $\alpha = \beta = \gamma$, as the portion of customers who choose either BB, BS, or SS instead of lost sales increases (i.e., the values of $\alpha$, $\beta$, and $\gamma$ increase), the following results are obtained:

A) The optimal order size ($q_{RSR}^\star$) of the non-integrated system first decreases and then increases from a certain value of $\alpha(= \beta = \gamma)$ in $\alpha$, $\beta$, and $\gamma$;

B) The optimal order size ($q_{ISR}^\star$) of the integrated system first decreases and then increases from a certain value of $\alpha(= \beta = \gamma)$ in $\alpha$, $\beta$, and $\gamma$;

C) The manufacturer’s maximum profit ($\pi_{M,SR}^\star$) in the non-integrated system first decreases and then increases. In contrast, the retailer’s maximum profit ($\pi_{R,SR}^\star$) in the non-integrated system always increases; and

D) The total profit ($\pi_{ISR}^\star$) in the integrated supply chain always increases.

Next, for a comparison between the non-integrated and the integrated models, assuming $\alpha = \beta = \gamma$, the following results are obtained:

E) The level of the customers’ responses at which the curve of the optimal order size changes from decreasing to increasing is greater in the integrated model than that for the manufacturer in the non-integrated model.

F) The total profit of the non-integrated system ($\pi_{R,SR}^\star + \pi_{M,SR}^\star$) is less than the optimal profit of the integrated system ($\pi_{ISR}^\star$) when the level of customers response is low; however, above a certain value of $\alpha(= \beta = \gamma)$, the profits is equivalent.

In general, the numerical examples show interesting outcomes: The order size and the manufacturer’s profit in the non-integrated system can be expressed with a V-shaped curve. Therefore, we find that the effect of customers’ active responses to stockout may have negative and positive effects on the order size and profit corresponding to the order size.

**Managerial Implications**

From these findings, we derived the following managerial suggestions:

1. Loyalty development is not always welcomed by the manufacturer.

   One suggestion from the numerical example (see Figure 5) is that building brand and/or store loyalty is always good for the retailer but not always for the manufacturer. As Table 2 shows, one may think that building store loyalty influences only a retailer’s performance and that brand loyalty affects the manufacturer’s performance. However, our finding implies that even building brand loyalty does not always guarantee a benefit for the manufacturer. In a real business environment, manufacturers are eager to develop brand loyalty for their products by offering various marketing strategies; however, our analysis suggests a potential risk that such efforts to develop brand loyalty will backfire in a certain situation. In other words, an adequate strategy for building brand loyalty should be determined that considers the behavior of customers regarding their active responses to unavailable items.

2. Brand and store loyalty can serve as the substitute for a supply chain contract to coordinate the system.
The numerical findings demonstrate the possibility that, from the viewpoint of the entire supply chain performance, a high enough level of customers’ active responses to stockout can coordinate the non-integrated supply chain without using a supply chain contract such as a buyback contract. Therefore, even if in general developing a high level of brand and store loyalty is beneficial for the chain, when the level of customers’ active responses to stockout is not high enough, some sort of a supply chain contract may be necessary to raise the performance of the entire chain to the level of the global optimum.

3. Brand management should be dynamically adjusted when the customers’ active responses to stockout change according to the stage of the product life cycle. Our numerical examples show that the optimal order size in the non-integrated system decreases when the level of the customers’ active responses to stockout increases but still remains low. As a result, there is a possibility that developing brand/store loyalty may damage the manufacturer’s profit if the loyalty level is not high, whereas such loyalty development always improves the retailer profit even at a low level. Therefore, one implication is that some mechanism to compensate for the negative effect of loyalty development on the manufacturer’s performance might be necessary at the initial stage of loyalty development for a product. In other words, we suggest the importance of dynamic brand management strategies: A manufacturer should dynamically adjust its strategic plan of brand loyalty enhancement from the viewpoint of product life cycle management; in particular, manufacturers should adequately collaborate with retailers at the early stage of a product life.

In conclusion, we find a case in which the intuitive understanding of the effects of backlogging, brand switching, and store switching on the retailer and the manufacturer (see Table 2) is not always true. In particular, our examples show that the effects of these three responses on firms differ depending on the portion of stockout customers who choose them.

CONCLUDING REMARKS

Assuming a two stage-supply chain of a manufacturer and $N$ homogeneous retailers that sell $M$ exchangeable products, this study provides an understanding of how consumer behavior regarding unavailability of a product that consumers originally want to buy influences the stock size of a firm and the negative effect due to double marginalization. A traditional newsvendor model considers only lost sales as a result of undersupply of products; however, our model, as an extension of a newsvendor model, includes backlogging, brand switching, and store switching in addition to lost sales. We then obtain several interesting results via numerical analysis. First, the intensity of customers’ active responses to stockout influences the optimal order size: The optimal order size decreases if the response increases while its level still remains low; however, the order size increases when the response level is high. Second, as more customers who face stockout of the preferred product choose backlogging, brand switching, or store switching (we call this “more customers actively respond to stockout”), a retailer can gain more profit but a manufacturer’s profit gain is not guaranteed if the response level is low. Third, as more customers actively respond to stockout, the gap between the non-integrated model and the integrated model decreases. This can be interpreted as if a certain number of customers experiencing stockout intend to choose backlogging, brand switching, or store switching instead of quitting the purchase (i.e., the levels of store and/or brand loyalty are high enough), there is a chance that a supply chain can be automatically coordinated without using some sort of supply chain contract designed to increase the performance of the non-integrated system (i.e., a local optimum) to that of the integrated system (i.e., a global optimum).
There remain many potential future research opportunities from this study. First, we use only numerical analysis. It is worth modifying the current models to analytically tractable ones and then analyzing them. Second, this study considers a manufacturer that applies an MTO production system and addresses only a buyback contract. Another future research direction is to consider the situation of an MTS manufacturer and other types of supply chain contracts. Third, our model uses only an order quantity \( q \) as a decision variable; however, the quality of research will be enhanced if other decision variables are included, such as retail price, quality level, and/or marketing effort.

**REFERENCES**


