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Designing Supply Chain Backorder Contracts for Customer Retention

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ABSTRACT

Stockout is an unfortunate event for businesses. While prior literature has focused on how to prevent stockouts from occurring, we study how supply chain firms can best react to them by converting a potential lost sale or customer into a retained backorder or customer when they do happen. In particular, we examine how an upstream supply chain firm may use an incentive contract with a downstream firm in an inventory system managed by either the downstream or upstream firm to retain customers in Business-to-Business markets. The upstream firm promises the downstream firm a certain level of compensation ex ante in exchange for efforts by the retailer to convert potential lost sales, due to stockouts, to backorders. The findings show that the inclusion of a backorder incentive contract may change firms' decision patterns. Significant differences between who manages the inventory in terms of inventory levels, prices to induce retailer backorder efforts, supply chain profits, and their sensitivity to factors such as long-term customer value, are explored and discussed. A contingent effort cost is also considered and the results are presented.

Key Words: Vendor Managed Inventory; Retailer Managed Inventory; Business-to-Business Market; Incentive; Backorders; Customer Retention.

JEL Code: C60

Designing Supply Chain Backorder Contracts for Customer Retention

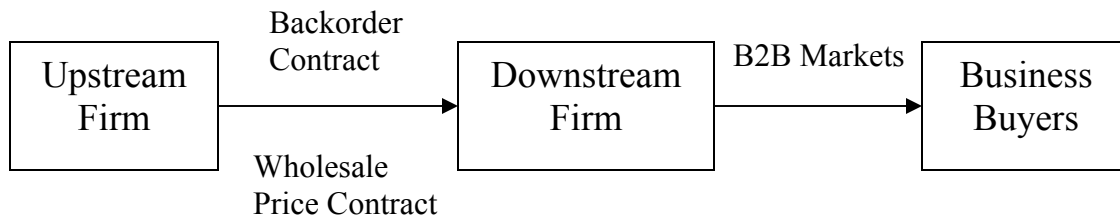
1. Introduction

Customer satisfaction has been at the center of marketing and operational effort to grow market share and improve competitive advantages (Thomas et al. 2004, Verhoef 2003, Hall and Porteus 2000). Operations and supply chain managers have particularly emphasized better managing product inventory and preventing stockouts to improve customer satisfaction and retention (Aberdeen Group 2004a). However, stockouts still inevitably occur. Stockout levels in the range of 10-30% have been shown to be the norm in the retail industry (Mason and Wilkinson 1976). A study of national supermarket chains showed that 8.2% of items were out of stock on a typical afternoon (Andersen Consulting 1996). These alarming statistics are also true in Business-to-Business (B2B) settings; for example, Yao et al. (2007) found that, on average, distributors in the electronic components industry experienced out of stocks about 2 days a week. Stockouts, consequently, may result in lost sales, or even worse, lost customers and the long-term value associated with them. As a result, a stream of research has emerged to study how to manage stockouts for improved customer service (e.g., Fitzsimons 2000, Anderson et al. 2006, Emmelhainz, et al. 1991, Walter and Grabner 1975). Its research setting focuses on the direct interaction between firms and their consumer customers. Little research has examined the topic between firms and their business customers, and from a supply chain perspective. The objective of this study is to fill the research gap by exploring design issues of a backorder contract between supply chain members in providing improved customer retention¹ in B2B markets². Figure 1 depicts our research setting.

¹ The notion of customer retention through backorders is discussed in Bendoly et al. (2005).

² We acknowledge that there are different types of B2B electronic markets (Kaplan and Sawhney 2000). In this research, we limit our focus to the B2B electronic markets that feature systematic sourcing so that transactions occur

Figure 1: Research Setting



There are two features of a B2B relationship that are distinct from a B2C relationship, and have been studied widely in the prior literature. First, a B2B relationship aims for a long term horizon. As stated by Gounaris (2005, p.126), “In most business-to-business (B2B) exchanges, achieving a sale is not the fulfillment of an effort but rather an event in a broader endeavor to build and sustain a long-term relationship with the customer and see that sales keep coming.” Second, B2B markets allow for greater information capture and more transparent information exchange between supply chain partners (Zhu 2004, Bakos 1991a). Thus, due to the long-term relationship and information transparency, the upstream firm is able to capture complete demand and outcome information when managing stockouts in a B2B market. It is thereby able to channel appropriate incentives for customer retention. When a business buyer places an order which is unfilled due to stockout at the downstream firm, the downstream firm is able to record the quantity of the stockout and share it with the upstream firm who supplies the products. In a non-B2B setting (e.g., B2C), however, capturing complete consumer demand information during stockouts can be difficult, as the consumers may simply walk away without revealing their unsatisfied needs.

regularly and repeatedly between the upstream and downstream firms. Auctions, reverse auctions and other spot sourcing methods are beyond of the scope of this research.

Managing stockouts in a supply chain setting is another challenge due to misaligned interests between firms in the supply chain. In the case of stockouts at the downstream firm, the buyer has the following options³: (1) the buyer can place a backorder; (2) the buyer can purchase a substitute product supplied by a competing upstream firm at the same downstream firm; (3) the buyer can purchase the desired product from a competing downstream firm; and (4) the buyer may choose not to purchase at all. In a retail setting, it was estimated that about 15% of buyers chose to place a backorder, 26% chose to purchase a competing brand, 31% chose to purchase the desired product from a competing store, and 9% chose not to purchase (Gruen et al. 2002). Although none of these options is desirable, the first scenario may be a relatively better solution in the unfortunate situation of a stockout, as it retains the customer through delay of delivery for both upstream and downstream firms. Other options result in a lost customer for the upstream firm (case 2), the downstream firm (case 3), or both (case 4). The interests of the upstream firm and the downstream firm are misaligned in that the upstream firm prefers the backorder solution in the case of stockout (Cachon 2001; Kraiselburd et al. 2004), whereas the downstream firm may be indifferent as long as the buyer purchases an alternative product with a similar margin. An incentive to induce the downstream firm to exert effort to retain customers through backorders is therefore needed in order to realign the interest in the supply chain.

This research is motivated by these challenges and the paucity of relevant literature focusing on a B2B and supply chain setting. In particular, we examine various contracting frameworks between supply chain parties that directly incorporate a backorder incentive contract to gain deeper understanding of whether such an addition could substantially change the conventional decisions. We also explore the impact of the contracting environment, with and without vendor managed inventory (VMI), on supply chain decisions with the backorder contract,

³ Assume no within brand substitution.

given that ownership structures can have a direct impact on price and demand for both buyers and suppliers (Yoo et al. 2007). Since VMI transfers the decision-making authority of replenishment from the downstream to the upstream firm, it may potentially affect the impact of the backorder contract. Furthermore, we investigate how the backorder contract should be designed for different conditions such as for buyers with high long-term value vs. those with low long-term value.

Our major findings indicate that, first, the inclusion of a backorder contract in the B2B environment may lead to different supply chain decisions in terms of order quantities and wholesale prices. In fact, under the backorder contract, the supply chain has a lower order quantity. Second, given the B2B based backorder contract, different supply chain decision making structures, i.e. Retailer-Managed Inventory (RMI)⁴ vs. VMI, lead to different decision patterns; specifically, the optimal order quantity is larger while the backorder price can be lower under VMI. Third, as lost customers may represent different long-term values to the supply chain firms, these firms respond differently, under RMI vs. under VMI, to such values. Interestingly, the manufacturer's profit decreases in the retailer's lost customer value, in expectation, under VMI, but increases under RMI. Fourth, other factors—backorder cost, outside price of alternative products, and the manufacturer's ability to infer retention effort from performance—may all contribute differently to supply chain decisions under RMI vs. under VMI. Finally, the nature of backorder cost, in terms of whether it is contingent on stockouts, may also affect supply chain decisions, under RMI and VMI.

These findings contribute to the supply chain management literature in two ways—first, our study specifically considers a backorder contract to improve supply chain decision-making,

⁴ RMI is used more generally in our paper. RMI refers to the case where the downstream firm (not necessarily a retailer) manages its inventory.

and is the first to do so to our best knowledge. This is made possible by the nature of information availability in the B2B environment. The addition of the backorder contract, however, does not seem to substantially alter the fundamental behaviors of the supply chain parties involved. Rather, it may impact specific supply chain decisions and how these decisions are affected by other supply chain factors. Second, it connects supply chain decisions to customer retention by proposing a replenishment-based contract, i.e. backorder contract, to directly tackle the issue of customer retention. This interdisciplinary approach sheds light on potential applications of backorders to retain customers from both the supply chain and marketing perspectives, whereas previous studies have focused on how to prevent stockouts from happening.

The rest of the paper is organized as follows. Section 2 presents a literature review; Section 3 develops the analytical model; Section 4 presents the main model results and discussions, along with an extension of our base model; and finally Section 5 draws conclusions from the research.

2. Literature Review

Three streams of research are relevant to our study. The first stream studies customer retention, the second stream studies issues related to backorder decisions, and the third stream studies VMI programs. We discuss these in detail and highlight the differences and contributions of our research in the following.

Customer retention or customer relationship management (CRM) in general has been studied extensively in the field of operations management and relationship marketing. Previous works have focused on assessment of CRM performance (e.g., Lewis 2004; Thomas et al. 2004; Reinartz et al. 2004), evaluation of drivers of customer satisfaction and retention (e.g., Chen and Hitt 2002; Brown and Chin 2004), allocation of resources (e.g., Reinartz et al. 2005), and the

structural design of a CRM system (e.g., Chu and Desai 1995). A number of papers that studied customer relationships in the B2B setting are particularly relevant to our paper. For example, [Jackson \(1985\)](#) concluded that the customer's overall assessment of the firm is a key determinant of customer retention in a B2B relationship. [Canon and Perreault \(1999\)](#) showed that business customers' evaluations of supplier performance vary across different types of relationships. [Gounaris \(2005\)](#) empirically investigated the influence of trust and commitment on customer retention in B2B services and found that the degree of trust between the service provider and the customer is directly affected by the quality of the service and the bonding strategy and techniques of the provider. A recent study by [Bolton et al. \(2008\)](#) studied customers' upgrade decisions in the B2B setting. They analyzed more than 2000 service contracts and found that decision-maker satisfaction, service quality and price have a significant effect on the decision to upgrade, and that price and satisfaction also moderate the effect of service quality on the decision.

Although sales and operations planning have been shown to be critical to success in customer retention ([Aberdeen Group 2004b](#)), however, research relating operational decisions such as backordering to customer retention has been sparse. Among these few studies, [Hall and Porteus \(2000\)](#) investigated how service failure and customer retention affect a company's capacity decision. [Iyer et al. \(2003\)](#) considered backordering a fraction of regular demands through demand postponement, assuming customer retention is not affected in such a practice. [Walter and Grabner \(1975\)](#) developed a stockout model through exploring a method of determining consumer reaction to retail stockout, and tested it using empirical data that demonstrate how varying responses can be translated into an economic cost to the retailer. [Anderson et al. \(2006\)](#) conducted a field study that measures the short- and long-run opportunity cost of a stockout. They showed that failing to account for the long-run effects of a stockout will

lead to suboptimal inventory decisions and that the adverse impact of a stockout extends to both other items in the current order and future orders.

The research setting in these studies focuses on the direct interaction between firms and their customers. Our study is different in that we focus on a supply chain setting and supply chain firms' ability to retain customers through converting stockouts to backorders. A few papers have examined a similar setting but with a different focus on supply chain coordination. Kraiselburd et al. (2004) studied contracting issues in a supply chain with stochastic demand and substitute products, and found that VMI is a better supply chain structure when manufacturer effort is a key driver of consumer demand and when consumers are unlikely to substitute to another brand in case of a stockout. Misha and Raghunathan (2004) compared VMI and RMI under brand competition and examined the incentives for downstream firms, such as retailers, to participate in VMI arrangements. They found that VMI intensifies competition among manufacturers of competing brands, thus providing benefits to retailers. Netessine et al. (2006) analyzed the inventory replenishment decisions of duopolistic retailers with customer backorders in a multi-period setting with exogenously given prices, but without any unobservable effort or demand information. They also examined how the retailer's monetary incentive to backordering customers affects the optimal inventory policy, and found that an increase in the incentive offered by one retailer leads to an increase in his own inventory but a decrease in the other retailer's inventory. Our model is different from these studies in two important areas. First, all of them assume a given degree of substitutability or probability to switch to a substitute; we model this parameter as a result of the downstream firm's effort. Second, none of them assumes that the downstream firm exerts any effort in converting the stockouts; we model that the downstream firm may expend effort in some situations or under incentives provided by the manufacturer. In

particular, since we focus on the incentive contract from an upstream firm to a downstream firm to stimulate customers backordering in a B2B environment, our study differs significantly from Netessine et al. (2006) who focused mainly on the (explicit) retailer-to-customer monetary reward.

Finally, a body of literature examines VMI through the lens of contracting theory. These papers focus on the design of a VMI system. For example, Fry et al. (2001) study VMI under a (z, Z) type contract, and find that the (z, Z) VMI contract performs significantly better than retailer managed inventory in many settings, but significantly worse in others. Plambeck and Zenios (2003) consider VMI in a principal-agent setting, such that the principal motivates the agent to control the production rate in a manner that minimizes the principal's total expected discounted cost. Unlike these studies, and many other related studies that discuss supply contracts and inventory decisions (e.g., Cachon 2001), our model features a two-level contracting framework with a retention performance-based backorder contract enabled by B2B technologies, along with a wholesale price and order quantity supply contract.

In summary, our research builds upon all three streams of literature. We develop a backorder based incentive mechanism that facilitates business customer retention in a supply chain setting. Little research from the three streams has studied using backorders as a strategic weapon for customer retention under the different collaboration structures of VMI and RMI. The paucity of such research points to the major contribution of our paper.

3. Analytical Model Framework

We model a single product supply chain in a principal-agent setting where the manufacturer acts as a principal and the retailer (i.e., the manufacturer's customer) acts as an agent. We use the notion of manufacturer-retailer supply chain for convenience and in parallel to

many related studies. The manufacturer and retailer correspond to the upstream and downstream supply chain firms in the B2B setting, as depicted in Figure 1. The retailer carries substitute products from competing manufacturers. In order to focus on the contracting issues and retain model tractability, we do not, however, explicitly include other manufacturers or their products in our model, but assume an asymmetric cost structure associated with lost sales to indicate that the retailer has, on average, less to lose than the manufacturer when a stockout occurs. This is because the retailer may sell a substitute product if the manufacturer's product is out of stock. The selling price for the product at the retailer is p , the purchase cost (i.e. the manufacturer's selling price) is w for regular orders and w_b for backorders at the retailer, and the marginal production cost for the manufacturer is v .

The retailer's backorder effort influences the extent to which lost sales stockouts are "converted" into backorders, and thus the extent to which customers are eventually retained. The effort, for example, includes the retailer's investment in training, education, and setting up effective and efficient electronic CRM systems and processes to facilitate the retention endeavor. The retailer may educate her sales associates as to the benefits of the manufacturer's product, or demonstrate how customers may be persuaded to place backorders, rather than substitute products, in the event of a stockout. Training to retain customers has been put into practice, for example, by Arrow Electronic, Inc. Arrow prepared its field sales representatives before servicing customers, with tremendous effort and substantial resources, to learn, explain, and promote new products from selected suppliers (Narayandas 2003). Other examples of such efforts to attracting customer backorders include free and expeditious shipping and handling to the customer location, free product samples, rain checks, and financial incentives. The extent of such retailer efforts is usually not known or verifiable by the manufacturer even with the B2B

arrangement, due to the spatial separation and the range and variety of investments and activities involved.

We denote the retailer's effort as e , and note that retailer effort is not directly observable by the manufacturer. We define two levels of effort, High (H) and Low (L), such that

$e \in \{e^H; e^L\}$. We denote the ratio of backorder stockouts to total stockouts as conversion rate θ ,

where $\theta \in \{\underline{\theta}; \bar{\theta}\}, 0 \leq \theta \leq 1$, which depends on the retailer's effort, and is unknown *ex ante*. We

assume that θ follows a conditional distribution: $Pr(\bar{\theta} | e^H) = P^H; Pr(\underline{\theta} | e^H) = 1 - P^H$;

$Pr(\bar{\theta} | e^L) = P^L; Pr(\underline{\theta} | e^L) = 1 - P^L$, which is common knowledge. We further assume that the

distribution satisfies first order stochastic dominance, suggesting that "good" results are more

likely to happen under high efforts, i.e., $P^H > P^L$. Let $\theta^H = P^H \bar{\theta} + (1 - P^H) \underline{\theta}$. The retailer

incurs an increasing cost for exerting effort, $c(e)$, with $c(e^H) > c(e^L)$, which is normalized as

$c(e^L) = 0$ and $c(e^H) = c > 0$. This cost of effort is independent of the number of stockouts; that

is, the cost is determined *ex ante* by the retention capabilities that are built to convert stockouts to

backorders before stockouts actually happen. Later, we will consider an alternative scenario

where the cost of effort is considered *ex post* to stockouts. In addition, demand distribution,

production and inventory related costs are all common knowledge and the manufacturer's

inventory policy is make-to-order. The manufacturer has unconstrained production capacity to

fulfill any number of backorders immediately. Overstocked products are disposed of by the

retailer at cost h_R (Cachon 2002).

The retailer faces a stochastic demand with a mean μ , a cumulative distribution function

$G(x)$ and a density function $g(x)$. All stockouts incur penalty costs for the manufacturer and the

retailer. The unit penalty cost for lost sales stockouts are l_M and l_R for the manufacturer and the

retailer, respectively, and $l_M > l_R$. l_M represents the long-term customer value to the manufacturer. The long-term customer value is based on the notion of Customer Lifetime Value (LTV), which is typically defined as the net present value (NPV) of the customer's profitability throughout the customer-firm relationship (Dwyer 1989). If a customer decides to terminate the relationship with a firm, the firm will lose the customer's LTV or entire future profits (assume the customer will not return).

The expected manufacturer and retailer profit functions are stated as follows:

$$E_X \pi_M(\theta) = (w - v)q + \int_q^{+\infty} [-l_M(1 - \theta) + (w_b(\theta) - v)\theta](x - q)g(x)dx \quad (1)$$

$$E_X \pi_R(\theta, e^j) = \int_0^q [(px - wq) - h_r(q - x)]g(x)dx + \int_q^{+\infty} [(p - w)q + (p - w_b(\theta))\theta(x - q) - l_R(1 - \theta)(x - q)]g(x)dx - c(e^j) \quad (2)$$

where $j = H, L$.

In the following sections, we examine the impact of backorder contracts under RMI and VMI, respectively.

3.1 Retailer-Managed Inventory (RMI)

Under RMI in a B2B environment, the retailer retains the traditional role in replenishment—the retailer places orders and the manufacturer fulfills the orders. The sequence of events in an RMI system is as follows:

1. The manufacturer (leader) and the retailer (follower) play a Stackelberg game. For a given wholesale price w , the retailer decides the order quantity (q). With the knowledge of this ordering behavior, the manufacturer finds the best wholesale price w to offer in order to maximize profit.

2. The manufacturer (principal) offers a backorder contract $w_b(\theta)$ to the retailer to induce backorder efforts. If the retailer rejects the contract, the retailer receives a reserved profit $\varphi=0$. If the retailer accepts the contract, the retailer exerts a backorder effort (e).
3. The demand X is realized, and if the demand exceeds the current order, the conversion rate θ based on the backorder effort level (e) that the retailer exercises is then realized. The backorder contract is then executed.

The manufacturer does not observe the retailer's effort directly, but due to the use of B2B based information technologies, can observe and contract on the *ex post* backorder conversion rate θ , which is a function of the effort, e , as described earlier. The manufacturer provides incentives for the retailer to exert a higher level of effort. In our model, it is always in the manufacturer's best interest that a higher effort is made by the retailer, as the extra effort does not incur additional costs to the manufacturer but increases sales through backorders. The incentive mechanism problem in stages 2 and 3 of the RMI process is stated as follows:

$$\text{Max}_{w_b(\theta)} E_{X,\theta|e^H} \pi_M = P^H E_X \pi_M(\bar{\theta}) + (1 - P^H) E_X \pi_M(\underline{\theta}) \quad (3)$$

subject to

$$\begin{aligned} \text{IC: } E_{X,\theta|e^H} \pi_R &= P^H E_X \pi_R(\bar{\theta}, e^H) + (1 - P^H) E_X \pi_R(\underline{\theta}, e^H) \\ &\geq P^L E_X \pi_R(\bar{\theta}, e^L) + (1 - P^L) E_X \pi_R(\underline{\theta}, e^L); \end{aligned} \quad (4)$$

$$\text{IR: } P^H E_X \pi_R(\bar{\theta}, e^H) + (1 - P^H) E_X \pi_R(\underline{\theta}, e^H) \geq 0; \quad (5)$$

$$\text{and, } v \leq w_b(\theta) \leq u. \quad (6)$$

The objective function is the manufacturer's expected profits. The individual rationality constraint (IR) reflects the minimum level of profits required by the retailer to accept the RMI contract. The incentive compatibility constraint (IC) states that the retailer will choose higher

efforts if they result in higher profits. The additional constraint reflects that the backorder prices are restricted to be above the manufacturer's production cost, v , and below an alternative outside wholesale price, u (such as the price of a similar product to which the retailer may switch when the backorder price is too high). This limited liability type of constraint may impose a limit on the range of optimal backorder contracts and therefore lead to Second Best solutions (Innes 1990; Sappington 1983).

Let $\tilde{G}(q) = \int_0^q G(x)dx$, which is the expected amount of overstock; and

$n(q) = \int_q^\infty (x - q)g(x)dx = (\mu - q) + \tilde{G}(q) > 0$, which is the expected amount of stockout.

For the problem in (3)~(6), since the objective function and constraints are linear in the backorder prices, one or more constraints will be binding. The binding IC constraint (4) leads to:

$$w_b(\bar{\theta})\bar{\theta} = [w_b(\underline{\theta})\underline{\theta} + (p + l_R)(\bar{\theta} - \underline{\theta})] - c / [(P^H - P^L)(\mu - q + \tilde{G}(q))]. \quad (7)$$

If the IR constraint in (5) becomes binding first, the First Best solution becomes the outcome, where the following condition is satisfied:

$$(p + h_R)\mu - (w + h_R)q + cP^H / (P^H - P^L) + [(p - u + l_R)\underline{\theta} - (p + h_R + l_R)](\mu - q + \tilde{G}(q)) - c < 0. \quad (8)$$

Otherwise, the limited liability constraint will become binding first, yielding $w_b(\underline{\theta}) = u$, considered as a Second Best, which is the focus of the following discussion. From (7),

$$E_{X, \theta | e^H} \pi_R = (p + h_R)\mu + cP^L / (P^H - P^L) - (w + h_R)q + [(p - u + l_R)\underline{\theta} - (p + h_R + l_R)](\mu - q + \tilde{G}(q)). \quad (9)$$

Given the incentive backorder contract, the manufacturer-retailer Stackelberg game is specified as follows:

$$\text{Max}_w E_{X, \theta | e^H} \pi_M$$

$$\text{S.t. } q^* = \arg \max_q E_{X, \theta | e^H} \pi_R, \text{ and}$$

$$E_{X, \theta | e^H} \pi_R(q^*) \geq 0.$$

Solving the retailer problem,

$$w = -h_R + [(p + h_R + l_R) - (p - u + l_R)\underline{\theta}](1 - G(q)). \quad (10)$$

Then the equilibrium order quantity can be solved from the first order condition (FOC) of the manufacturer's profit function:

$$\begin{aligned} F(q) = & -(v + h_R) - q \{ [p + h_R + l_R - (p + l_R - u)\underline{\theta}]g(q) \} \\ & + [(v + h_R) + (p + l_R + l_M - v)(1 - \theta^H)](1 - G(q)) = 0, \end{aligned} \quad (11)$$

after applying (10).

The following lemma summarizes the optimal outcomes, with a superscript "R" denoting the optimal decisions or profits under RMI.

Lemma 1. In RMI, the optimal backorder prices, wholesale price, and order quantity are:

$$w_b^R(\underline{\theta}) = u,$$

$$w_b^R(\bar{\theta}) = \left\{ u\underline{\theta} + (p + l_R)(\bar{\theta} - \underline{\theta}) - c / \left[(P^H - P^L)(\mu - q^R + \tilde{G}(q^R)) \right] \right\} / \bar{\theta},$$

$$w^R = -h_R + [(p + h_R + l_R) - (p - u + l_R)\underline{\theta}](1 - G(q^R)), \text{ and}$$

$$\begin{aligned} & -(v + h_R) - q^R \{ [p + h_R + l_R - (p + l_R - u)\underline{\theta}]g(q^R) \} \\ & + [(v + h_R) + (p + l_R + l_M - v)(1 - \theta^H)](1 - G(q^R)) = 0. \end{aligned}$$

3.2 Vendor-Managed Inventory (VMI)

The sequence of events under a VMI system in a B2B environment where the manufacturer makes decision on order quantity for the retailer is now as follows:

1. The manufacturer decides the order quantity (q) for the retailer, along with his own wholesale price w , based on the manufacturer's profit expectation. The retailer either takes it or leaves it with no profit.
2. The manufacturer (principal) offers a contract $w_b(\theta)$ to the retailer to induce backorder efforts. If the retailer rejects the contract, the retailer receives a reserved profit $\varphi=0$. If the retailer accepts the contract, the retailer makes a backorder effort (e).
3. The demand X is realized, and if the demand exceeds the current order, the conversion rate θ based on the backorder effort level (e) that the retailer exercises is then realized. The backorder contract is then executed.

In this case, the manufacturer's problem in stages 2 and 3 is still captured by (3)~(6), with related results in (7)~(9). Now, according to the VMI agreement, the manufacturer will set the retailer's order q along with her own wholesale price w , to maximize its own profit $E_{X,\theta|e^H}\pi_M$, subject to the retailer participation constraint of $E_{X,\theta|e^H}\pi_R \geq 0$. However, for a given q , the

manufacturer will maximize its profit by increasing w such that $E_{X,\theta|e^H}\pi_R = 0$ in (9), leading to

$$wq = (p + h_R)\mu + cP^L / (P^H - P^L) - h_Rq + [(p - u + l_R)\underline{\theta} - (p + h_R + l_R)](\mu - q + \tilde{G}(q)). \quad (12)$$

Incorporating this into $E_{X,\theta|e^H}\pi_M$, we have

$$E_{X,\theta|e^H}\pi_M = -[(v + h_R) + (p + l_R + l_M - v)(1 - \theta^H)](\mu - q + \tilde{G}(q)) - c - (v + h_R)q + [p + h_R]\mu \quad (13)$$

resulting in the following FOC of the manufacturer's profit function in relation to order quantity

q :

$$1 - G(q) = (v + h_R) / [(v + h_R) + (p + l_R + l_M - v)(1 - \theta^H)]. \quad (14)$$

Similar to the RMI case, the following lemma summarizes the results under VMI, with a superscript “V” denoting the optimal decisions or profits in VMI.

Lemma 2. In VMI, the optimal backorder prices, wholesale price, and order quantity are:

$$\begin{aligned}
w_b^V(\underline{\theta}) &= u, \\
w_b^V(\bar{\theta}) &= \left\{ u\underline{\theta} + (p + l_R)(\bar{\theta} - \underline{\theta}) - c / \left[(P^H - P^L)(\mu - q^V + \tilde{G}(q^V)) \right] \right\} / \bar{\theta}, \\
(w^V q^V \Rightarrow p + h_R \mu + cP^L / (P^H - P^L) - h_R q^V \\
&\quad + [(p - u + l_R)\underline{\theta} - (p + h_R + l_R)](\mu - q^V + \tilde{G}(q^V)), \text{ and} \\
(-v + h_R) &+ [(v + h_R) + (p + l_R + l_M - v)(1 - \theta^H)](1 - G(q^V)) = 0.
\end{aligned}$$

Lemmas 1 and 2 indicate that the low-conversion-rate backorder price is set at the outside wholesale price, whereas the high-conversion-rate backorder price is lower than the outside price. The difference between the high and the low type of wholesale prices depends on the differences between the high-low conversion rate and between the high-low efforts (e.g., how likely the high conversion rate is to occur for a given type of effort). The lower value for the high-conversion-rate backorder price is necessary in order to attract the retailer to exert the best effort to retain the end customers for the manufacturer. The lower such a price, the more the manufacturer compensates for such retailer effort. [Note: we assume

$$w_b^V(\bar{\theta}) = \left\{ u\underline{\theta} + (p + l_R)(\bar{\theta} - \underline{\theta}) - c / \left[(P^H - P^L)(\mu - q^V + \tilde{G}(q^V)) \right] \right\} / \bar{\theta} \geq v.]$$

The optimal order quantity under VMI is the first best because the limited liability constraint that results in the second best order quantity under RMI becomes irrelevant under VMI.

As the backorder contract becomes feasible in the B2B environment and is enabled by B2B applications, it may serve as a unique contracting option for supply chain firms. It is therefore interesting to investigate whether the addition of this backorder contract would have any direct impact on the nature of the conventional supply chain decisions. In a more

conventional supply chain environment without B2B technologies, the manufacturer could not conveniently observe the potential number of customers lost, and thus could not implement a backorder contract to motivate the retailer. Instead, the sequence of events under both RMI and VMI only consists of stages 1 and 3 above, with low backorder effort level from the retailer expected (accordingly $\theta = \theta^L$ in expectation) and $w_b = u$. The direct impact of incorporating the backorder contract in the conventional environment, under both RMI and VMI, is provided in Proposition 1 below.

Proposition 1. In comparison with a situation without the backorder contract,
 (a) the optimal order quantity is smaller with the backorder contract under RMI and VMI.
 (b) the optimal wholesale price is greater with the backorder contract under RMI.

This result indicates that the addition of the backorder contract indeed changes supply chain decisions. In particular, with the addition of the backorder contract, the manufacturer under RMI would provide a lower overall backorder price to motivate the retailer to exert High efforts in retaining final customers. The resulted higher percentage of customers retained in turn allows the retailer to order a smaller inventory and the manufacturer to charge a higher wholesale price. On the other hand, the implementation of the backorder contract under VMI allows the manufacturer to provide a lower overall backorder price to better encourage retailer efforts. But again, with the resulting higher percentage of customers retained, the manufacturer making the ordering decision for the retailer could afford to lower the order quantity to save the overage cost. More generally, the manufacturer equipped with the backorder contract in the B2B setting has a new proactive means to retain some potentially lost customers and could leverage such capability in a supply chain. Therefore, the addition of the backorder contract leads to a lower inventory level than the conventional setting, regardless of the supply chain structure (RMI or VMI).

4. Model Results and Discussion

As discussed above, RMI and VMI may be different in terms of inducing the retailer's best efforts to retain dissatisfied customers through backorder contracts. In this section, we contrast the optimal supply chain decisions and their performance between RMI and VMI by introducing a number of propositions.

Proposition 2. (a) $q^R < q^V$, (b) $w_b^R(\underline{\theta}) = w_b^V(\underline{\theta}) = u$, and (c) $w_b^R(\bar{\theta}) > w_b^V(\bar{\theta})$.

Proposition 2(a) shows that the replenishment order quantity is higher under VMI than under RMI. This is not surprising, because it is in the best interest of the manufacturer to reduce stockouts through increasing order quantity when he has the control over order quantity. This result is consistent with the findings in prior research related to VMI (e.g., Cachon 2001).

Proposition 2(b) shows that when a low conversion rate is achieved by the retailer, the manufacturer charges the same and highest possible (or it will lose the retailer to his competitor who offers price u) backorder price in both VMI and RMI. In contrast, as shown in Proposition 2(c), when a high conversion rate is achieved by the retailer, the manufacturer charges a lower backorder price as a form of compensation to the retailer, to motivate the retailer to make the best effort in retaining customers. The backorder price is lower under VMI than under RMI because the manufacturer has already stocked a higher quantity at the retailer and by offering a lower backorder price he can further reduce her eventual stockouts through the retailer's customer retention endeavor.

The following results show the different impacts of lost customer values on the manufacturer profit between RMI and VMI.

Proposition 3. (a) The expected manufacturer profit decreases less in the manufacturer lost customer value under VMI than under RMI.
 (b) The expected manufacturer profit decreases in the retailer lost customer value under VMI but increases in the retailer lost customer value under RMI.

Proposition 3(a) indicates that the expected manufacturer profit under both VMI and RMI decreases in the manufacturer lost customer value, and that the decrease is smaller under VMI than under RMI. It is intuitive that when a customer that is lost due to stockouts is of high value to the manufacturer, this will hurt the manufacturer's profit to a larger degree. However, the manufacturer's profit loss is less sensitive to the manufacturer's customer value under VMI than under RMI. This is due to the fact that the manufacturer will experience a smaller number of stockouts and lost sales under VMI. Interestingly, Proposition 3(b) shows that the manufacturer's profit increases in the retailer's lost customer value under RMI, suggesting that when the retailer values a customer, she may not need as much incentive from the manufacturer to retain the customer, thereby leading to a higher manufacturer's profit. A situation in which a retailer values its customer is when the retailer faces severe competition. For example, there may be another competing retailer nearby, so that unsatisfied customers can easily search and switch. This is often the case for Internet retailing, where competition is often much severe than in traditional retailing (Bakos 1991b). Since the Internet reduces buyers' search costs (Bakos 1997), retailers face great competition and are penalized more if a customer is lost to a competitor. Therefore, the implication of this result is that when the cost structure is not too asymmetric (i.e., the manufacturer is not penalized much more than the retailer for a lost customer), RMI is preferred to VMI. The manufacturer may want to take control of stocking decisions to better manage customer retention if his incentive is much greater than the retailer's.

- Proposition 4.** (a) The expected manufacturer profit increases more under RMI in the manufacturer's ability to infer retailer effort than under VMI.
(b) The expected manufacturer profit decreases more under RMI in the cost of customer retention (via backorders) than under VMI.
(c) The expected manufacturer profit increases in the outside wholesale price under RMI, but is not affected by it under VMI.

This proposition shows more interesting impacts of different factors on the manufacturer profit, under RMI vs. under VMI. First, the higher the probability for a “good” outcome (high conversion rate) under the High effort, the higher the manufacturer’s profits are in both cases, as might be expected. This probability can be further interpreted as the ability of the manufacturer to infer the effort made by the retailer to retain customers from the conversion rate. Therefore, this result suggests that when the conversion rate information the manufacturer observes can better infer the retailer’s effort, the manufacturer pays a lower level of compensation for the effort and improves his own profitability. However, such effect is stronger under RMI, because the price-only contract the manufacturer uses under RMI implies a higher level of compensation needed to induce a high level of retailer effort, and has a limited ability to take away retailer profit due to linearity of the price contract. A lower compensation resulting from the better ability to infer retailer effort directly, under RMI, benefits the manufacturer who does not have direct control over the replenishment process.

Second, the higher cost of retailer effort to retain customers will reduce the manufacturer’s profit, under RMI to a greater extent than under VMI according to Proposition 4(b). This happens because under VMI, the manufacturer could recuperate part of the compensation paid to the retailer during the backorder process, through the order replenishment process, by extracting the excess profit from the retailer. Third, the higher outside backorder price (u), which serves as the upper limit for the optimal backorder price, would allow the manufacturer under RMI to charge a higher backorder price for the “bad” outcome (low conversion rate), in order to discourage the retailer from shirking. The higher optimal backorder price contributes to a higher level of manufacturer profit. Under VMI, however, such a change in the outside backorder price has no effect on the manufacturer’s profit, as the manufacturer

always balances the backorder price and the replenishment process. In this case, this absorbs the increase in the upper limit for the backorder price without affecting the manufacturer's profit.

- Proposition 5.** (a) The optimal order quantity under VMI increases in both the manufacturer's and the retailer's lost customer values.
(b) The optimal order quantity under RMI increases in the manufacturer's lost customer value but is undetermined in the retailer's lost customer value.
(c) The optimal order quantities under RMI and VMI both decrease in the manufacturer's ability to infer retailer effort.
(d) The optimal order quantity decreases in the outside wholesale price under RMI but is not affected by it under VMI.

The effects of factors such as customer values and backorder effectiveness (cost of effort and probability of a high conversion rate at High effort) on the optimal order quantity can be considered more important because of their implications on supply chain planning decisions. In particular, as Proposition 5(a) suggests, when the manufacturer faces end customers of high value to the manufacturer under VMI, a higher order quantity is a natural choice because by increasing the order quantity, total stockouts can be reduced to better satisfy these high-value customers. Similarly, the higher the customer value to the retailer, the higher the order quantity. This is because under VMI, the retailer is more willing to make effort, and to incur a higher cost, to retain a higher value customer, and this higher cost is shared with the manufacturer under VMI where the manufacturer is better equipped to coordinate the supply chain and to integrate the retailer's costs and profit into the supply chain. It is therefore to the best interest of the manufacturer to balance this increased cost with an increased order quantity, which reduces total stockouts and lost customers.

However, as indicated in Proposition 5(b), this is not the case under RMI, which delegates the replenishment decisions to the retailer. While the argument above remains valid for RMI when the manufacturer's lost customer value is higher, it is more complicated when the retailer's lost customer value becomes higher. The retailer in this case can choose either

increasing the order quantity, which is under the retailer's control with RMI, or making the High effort to retain customers at an increased cost that will later be better compensated by the manufacturer. While an increased order quantity may very much remain the optimal choice, as in the case under VMI, it is also likely that the strength of the incentive instruments, backorder prices in this case, is strong enough that the order quantity may indeed decrease

Furthermore, Proposition 5(c) indicates that the better the ability to infer retailer effort from realized conversion rate, the lower the order quantity. This is because the incentive instruments, or backorder prices, become more effective and efficient when the realized conversion rate can be more informative in terms of inferring retailer effort. Compensating the retailer via backorder contracts then becomes a more efficient choice than increasing order quantity to avoid losing the customer with a higher value. When the outside wholesale price, serving as a ceiling for backorder prices, is higher, backorder price contracts become more efficient. This is because the added flexibility under a higher backorder price leads to a more likely alignment of manufacturer and retailer objectives. Proposition 5(d) indicates that, given this backorder contract, the retailer is better off choosing a smaller order quantity under RMI because of more favorable backorder compensation. Under VMI, the increased efficiency in coordinating the supply chain is completely realized by the manufacturer without requiring any change in order quantity.

Proposition 6. While the low-type backorder price is always constant, the high-type backorder price (a) increases in the manufacturer's ability to infer retailer effort under both RMI and VMI, and (b) increases more under RMI in the outside wholesale price than under VMI.

Any increase in the manufacturer's ability to infer retailer effort from the conversion rate makes the backorder contract more efficient. In particular, discerning the retailer's high/low effort requires less separation of high/low-conversion-rate backorder prices. For instance, the

high conversion rate is more likely the result of a high retailer effort, which in turn is more easily motivated. As the low-type backorder price is already pinned to the outside wholesale price as an outcome of the incentive mechanism, the high-type backorder price can be increased to capitalize on the improved efficiency of this incentive instrument, hence Proposition 6(a). By the same token, an increased outside wholesale price allows a more flexible and efficient backorder contract that raises the high-type backorder price. Similar to the argument established earlier, the effect is stronger under RMI when the retailer determines the order quantity and can better utilize the substitutability between a larger order quantity and a higher effort to retain customers.

It would also be interesting to understand the performance difference between RMI and VMI. The result of this analysis is summarized in the following proposition.

Proposition 7. The manufacturer's and the supply chain's profit under VMI are equal to or greater than those under RMI, respectively.

Intuitively, the manufacturer as a principal under VMI could extract as much retailer profit as allowed under the retailer's participation constraint with the control of both wholesale price and order quantity decisions. The manufacturer could still induce the best backorder effort from the retailer by implementing the backorder incentive contract. On the other hand, under RMI the manufacturer's ability to extract the retailer's profit is limited by the lower degree of control of decisions (wholesale price only as opposed to both wholesale price and order quantity under VMI), which leads to less (the same at best) profit for the manufacturer than under VMI. This also implies that, given that the retailer's profit has been fully extracted by the manufacturer under VMI, the manufacturer's profit is the supply chain profit and is maximized. Hence, the supply chain profit under RMI could only be lower, as the decision scope is smaller.

Further numerical analysis is conducted to understand the profit difference between RMI and VMI. For illustration, we assume that demand follows normal distribution, and set $p=50$,

$u=45, v=15, c=40, l_M=10, l_R=5, h_R=6, \bar{\theta}=0.8, \underline{\theta}=0.5, P^H=0.7, P^L=0.3, \mu=100,$ and $\sigma=10$.

Figures 2 and 3 show how changes in the customer conversion rate ($\bar{\theta}$) and outside wholesale price (u) affect the manufacturer's profit under RMI and VMI.

(Insert Figures 2 and 3 about here)

As Figure 2 demonstrates, the manufacturer's profit increases in the conversion rate $\bar{\theta}$ under both RMI and VMI, while that under VMI is always greater than that under RMI. Since the increase under RMI is faster than that under VMI, the gap in the manufacturer's profit between RMI and VMI is smaller under a higher $\bar{\theta}$. The principal driver of such difference could be the order quantity decision. As explained in Proposition 2, the optimal order quantity is higher under VMI than under RMI, leading to a much larger chance of stockouts under RMI. Thus, the improvement of either $\bar{\theta}$ or P^H (indications of better customer retention results with High effort when stockouts occur) will help the manufacturer more under RMI, as more customers are retained or "converted".

Interestingly, Figure 3 shows that the manufacturer's profit is unchanged with the outside wholesale price (u) under VMI, but increases in u under RMI. This is due to the implementation of the two stage contract. Under VMI, the manufacturer's "loss" to the retailer at the backorder stage, because of lower backorder prices set in response to a lower outside wholesale price, could be recuperated from a more favorable wholesale price at the ordering stage. Thus, the manufacturer's total profit under VMI is insensitive to the change of outside wholesale price (u). On the other hand, the manufacturer does not have such wholesale pricing flexibility under RMI and will benefit from a higher outside wholesale price (u), which makes the retailer less likely to choose the outside option in the case of stockouts.

The Case of Contingent Effort Cost

A possible scenario arises when the total cost of the retailer backorder effort is contingent on the occurrence of stockout. For instance, the retailer's employees exert efforts to persuade the unsatisfied customers, resulting in a total time and cost spent proportional to the amount of stockout. Let c_b denote *ex post* contingent cost, i.e., proportional to the number of stockouts (to avoid confusion with the quantity-independent effort cost). While this does not affect the manufacturer's profit function, the retailer's profit function is revised as:

$$E_X \pi_R(\theta, e^j) = \int_0^q [(px - wq) - h_R(q - x)] g(x) dx + \int_q^{+\infty} [(p - w)q + (p - w_b(\theta))\theta(x - q) - l_R(1 - \theta)(x - q) - c_b(e^j)(x - q)] g(x) dx, \quad (15)$$

where $j = H, L$. Again, we normalize the effort costs as $c_b(e^L) = 0$ and $c_b(e^H) = c_b$.

The manufacturer's incentive mechanism in stages 2 and 3 reflected in (3)~(6) remains unchanged, which allows the IC to be rewritten as:

$$(P^H - P^L) [-w_b(\bar{\theta})\bar{\theta} + w_b(\underline{\theta})\underline{\theta} + (p + l_R)(\bar{\theta} - \underline{\theta}) - c_b / (P^H - P^L)] (\mu - q + \tilde{G}(q)) \geq 0. \quad (16)$$

Similarly, the optimal backorder price is stated as

$$w_b(\bar{\theta})\bar{\theta} = w_b(\underline{\theta})\underline{\theta} + (p + l_R)(\bar{\theta} - \underline{\theta}) - c_b / (P^H - P^L). \quad (17)$$

Thus, the retailer's expected profit under high effort is given by

$$E_{X, \theta | e^H} \pi_R = (p + h_R)\mu - (w + h_R)q + [(p - u + l_R)\underline{\theta} - (p + h_R + l_R) + c_b P^L / (P^H - P^L)] (\mu - q + \tilde{G}(q)) \quad (18).$$

That is, the solution structure is similar to the previous model but with some notable differences, as described in the following proposition.

Proposition 8. The optimal supply chain decisions in RMI and VMI under contingent effort cost are as follows:

$$(a) \quad w_b^R(\underline{\theta}) = w_b^V(\underline{\theta}) = u, \quad w_b^R(\bar{\theta}) = w_b^V(\bar{\theta}) = [w_b(\underline{\theta})\underline{\theta} + (p + l_R)(\bar{\theta} - \underline{\theta}) - c_b / (P^H - P^L)] / \bar{\theta}.$$

(b) $q^R < q^V$ but they are higher than their respective quantities under fixed effort cost.

This proposition suggests a significant reversal of contrasting patterns of RMI and VMI decisions. In particular, both RMI and VMI will result in the same set of backorder prices to induce the best retailer effort, unlike in the case discussed above. This is because the retailer only needs to be compensated for her effort after the stockouts occur, so the manufacturer only needs to design the compensation scheme on a per unit of stockout basis, regardless of the original order quantity or inventory that causes such stockout to occur. On the other hand, with contingent effort cost, the order quantity under VMI is still higher than under RMI, with essentially the same trade-offs between them. However, both quantities with contingent effort cost are higher than their respective counterparts with the long-term (or fixed) effort cost described earlier. Intuitively, this is because with contingent cost (or variable cost), it is more advantageous to have relatively high order quantities to reduce the occurrence of stockouts and thus the related effort cost. In the case of long-term effort cost, which needs to be incurred regardless of stockout quantity, the advantage of large order size is substantially negated.

5. Concluding Remarks

The widespread B2B markets in supply chain allow more complete customer information capture and greater information transparency, which facilitates implementation of supply chain contracts. A backorder contract is one of the supply chain contracts that depend on the performance information of retained customers in the form of backorders. This study explored supply chain incentive contracts that can be implemented to retain customers via backorders. Specifically, two levels of contracts, backorder contract as well as wholesale price and order quantity contract, have been established under two supply chain governance structures, RMI and VMI. Optimal contracts were developed and the key properties of these contracts were examined

on important supply chain and customer service factors such as long-term values of lost customers, the extent to which retailer effort can be inferred from customer retention performance, etc. The findings provide important insights into managing customer retention in a supply chain via incentive contracts, as well as implications of contract design issues in B2B markets and supply chain settings.

The main results show that, first, an optimal backorder contract, as a direct incentive mechanism to induce retailer effort in customer retention, is attainable under a backorder price constraint. This result establishes potentially second-best backorder performance and allows customer retention to be managed separately from other marketing and operational decisions. However, the backorder contract has immediate impact on supply chain decisions on order quantity and wholesale price, leading to differences in supply chain profitability. Second, both the backorder contract and order quantity decisions may vary according to the structure of supply chain governance (i.e., RMI vs. VMI). The optimal backorder prices are higher, while the optimal order quantity is lower under RMI. Third, the backorder contract, order quantity decisions, and supply chain performance are usually sensitive to other market and supply chain factors, such as customer values to the retailer and manufacturer. The relationships between these factors and supply chain decisions and performance are further complicated by the structure of supply chain governance. In fact, they vary substantially under RMI vs. VMI. Specifically, the manufacturer benefits from a higher retailer value of a lost customer under RMI, but the manufacturer is worse off under VMI when this value is higher. While the manufacturer can generally benefit from a better ability to infer retailer effort from the realized conversion rate, this occurs more so under RMI. The manufacturer's profit increases under RMI when the outside wholesale price, which can be an alternative if the backorder price is too high, is higher, but

remains unchanged under VMI. Optimal supply chain decisions, such as order quantities and backorder prices, also respond to changes in the market and supply chain factors in different ways along RMI and VMI. Finally, when the retailer's effort to convert stockouts to backorders is more focused and only subject to the occurrence of stockouts, the optimal supply chain decision patterns can be quite different from the patterns seen when the effort is long-term and broad. For example, backorder prices become the same under RMI and VMI, while their order quantities with contingent effort cost are greater than those with long-term effort cost, respectively.

This research makes the following important contributions to the supply chain literature. First, it focuses on backorder conversion as an important source of customer retention, which to our best knowledge has not been studied in the previous supply chain literature, although backorder conversion measures have been widely implemented in various industries. In this study, we developed an incentive contracting approach to explicitly capture the retailer's effort in turning lost sales into backorders and discussed properties of the incentive contracts. Second, backorder and supply chain contracts have been studied under different supply chain governance structures, RMI vs. VMI, which show significantly different effects on the effectiveness and efficiency of the contracts, supply chain decisions, and performances. While such supply chain structures have been well studied in supply chain management, the impacts of supply chain structures on customer retention via backorder conversion and related supply chain contracts and decisions have remained under-researched; these impacts have been the focus of the this study. Third, this research contributes to the marketing literature, particularly customer relationship management, by proposing that customers can and should be retained through a coordinated effort by supply chain partners, and that lost sales need not, and should not, become lost

customers. Under a well-designed and well-executed incentive mechanism as outlined in our research, backorder conversion can become an important source of increased revenue, profit, and customer retention during unfortunate stockout situations.

This research has a number of implications for practitioners. First, although it is best to prevent stockouts from occurring, managers should realize that there are effective ways to retain a sale or customer when stockouts do occur. Second, managers in the upstream firms should be proactive in retaining customers at their downstream partners through implementable incentive contracts. Third, managers should understand that, to exploit the incentive mechanism to the fullest extent, the incentive contracts may be designed in different ways for different inventory ownership structures such as RMI vs. VMI.

Finally, this research also points to several directions for future research. First, the current model considers only a supply chain dyad consisting of a manufacturer and a retailer. Although a competing manufacturer is implicitly reflected through the manufacturer's asymmetric cost structure, the competition between manufacturers for sales at the retailer's location is not explicitly modeled. Future research that models competing manufacturers may provide deeper insights into the strategic behaviors of the focal manufacturer and retailer. Second, since most of the information is captured in the B2B setting, future research may collect such information and conduct empirical analyses to directly test some of our findings. Such empirical studies should complement our analytical work and provide richer insights into how to contract backorders for customer retention.

References

AberdeenGroup (2004a), "Supply Chain Inventory Strategies Benchmark Report: How Inventory Misconceptions and Inertia Are Damaging Companies' Service Levels and Financial Results",

- December 2004, <http://www.aberdeen.com/>.
- AberdeenGroup (2004b), “The Sales and Operations Planning Benchmark Report: Leveraging S&OP for Competitive Advantage”, June 2004, <http://www.aberdeen.com/>.
- Andersen Consulting (1996). “Where to Look for Incremental Sales Gains: The Retail Problem of Out-of-Stock Merchandise.” The Coca-Cola Retailing Research Council, Atlanta.
- Anderson, E.T., G.J. Fitzsimons, and D. Simester. (2006). “Measuring and Mitigating the Costs of Stockouts.” Management Science **52**(11): 1751-1763.
- Bakos, Y. J. (1991a). “Information Links and Electronic Marketplaces: The Role of Interorganizational Information Systems in Vertical Markets.” Journal of Management Information Systems **8**(2), pp. 31-52.
- Bakos, Y. J. (1991b). “A Strategic Analysis of Electronic Marketplaces.” MIS Quarterly, pp. 295-310.
- Bakos, Y. J. (1997). “Reducing Buyer Search Costs: Implications for Electronic Marketplaces.” Management Science **43**(12), pp. 1676-1692.
- Bendoly, E., J.D. Blocher, K.M. Bretthauer, S. Krishnan, and M.A. Venkataramanan. (2005). “Online/In-Store Integration and Customer Retention.” Journal of Service Research, **7**(4) 313-327.
- Bolton, R.N. K.N. Lemon, and P.C. Verhoef. (2008). “Expanding Business-to-Business Customer Relationships: Modeling the Customer’s Upgrade Decision.” Journal of Marketing **72**: 46-64.
- Cachon G. (2001). “Stock Wars: Inventory Competition in a Two-Echelon Supply chain with Multiple Retailers.” Operations Research **49**(5): 658-674.
- Cachon G. (2002). “Supply Chain Coordination With Contracts” Handbooks in Operations

Research and Management Science: Supply Chain Management. Edited by Steve Graves and Ton de Kok. North-Holland.

Emmelhainz, L.W., M.A. Emmelhainz, and J.R. Stock (1991). Logistics Implications of Retail Stockouts.” Journal of Business Logistics 12(2): 129-142.

Fitzsimons, G.J. (2000). “Consumer Response to Stockouts.” Journal of Consumer Research 27: 249-266.

Fry, M.J., R. Kapuscinski, and T.L. Olsen (2001). “Coordinating Production and Delivery Under a (z, Z)-Type Vendor-Managed Inventory Contract.” Manufacturing & Service Operations Management 3(2): 151-173.

Gounaris, S.P. (2005). “Trust and Commitment Influences on Customer Retention: Insights from Business-to-Business Service.” Journal of Business Research 58: 126-140.

Gruen, T.W., D.S. Corsten, and S. Bharadwaj. (2002). “Retail Out of Stocks: A Worldwide Examination of Extent, Causes, and Consumer Responses.” Working Paper.

Hall, J. and E. Porteus (2000). “Customer Service Competition in Capacitated Systems.” Manufacturing & Service Operations Management 2(2): 144-165.

Innes, R. D. (1990). “Limited Liability and Incentive Contracting with Ex-ante Action Choices.” Journal Economic Theory 52(1):45-67.

Iyer, A.V., V. Deshpande and Z. Wu (2003). “A Postponement Model for Demand Management.” Management Science 49(8): 983-1002.

Kaplan, S. and M. Sawhney. (2000). “E-Hubs: The New B2B Marketplaces.” Harvard Business Review, May-June, pp. 97-103.

- Kraiselburd, S., V.G. Narayanan, and A. Raman. (2004) "Contracting in a Supply Chain with Stochastic Demand and Substitute Products." Production and Operations Management **13**(1): 46-62.
- Mason, J.B. and J.B. Wilkinson. (1976). "Mispricing and Unavailability of Advertised Food Products in Retail Food Outlets." Journal of Business **49**(2): 219-225.
- Mishra, B.K. and S. Raghunathan. (2004). "Retailer- vs. Vendor-Managed Inventory and Brand Competition." Management Science. **50**(4): 445-457.
- Netessine, S., N. Rudi and Y. Wang (2006). "Inventory Competition and Incentives to Backorder." IIE Transactions **38**(11): 883-902.
- Plambeck, E.L. and S.A. Zenios (2003). "Inventive Efficient Control of A Make-To-Stock Production System." Operations Research **51**(3): 371-386.
- Reinartz, W., J.S. Thomas, and V. Kumar (2005). "Balancing Acquisition and Retention Resources to Maximize Customer Profitability." Journal of Marketing **69**(1): 63-79.
- Sappington, D. E. M. (1993). "Limited Liability Contracts between Principal and Agent." Journal of Economic Theory **29**(1):1-21.
- Thomas, J., R. Blattberg and E. Fox (2004). "Recapturing Lost Customers." Journal of Marketing Research, 41 (February): 31-45.
- Verhoef, P.C. (2003). "Understanding the Effect of Customer Relationship Management Efforts of Customer Retention and Share of Customer." Journal of Marketing, **67**(4): 30-46.
- Walter, C.K. and J.R. Grabner. (1979). "Stockout Cost Models: Empirical Tests in a Retail Situation." Journal of Marketing **39**: 56-68.
- Yao, Y., P.T. Evers, and M.E. Dresner. (2007). "Supply Chain Integration in Vendor Managed Inventory." Decision Support Systems **43** (2): 663-674.

- Yoo, B., V. Choudhary, and T. Mukhopadhyay. (2007). "Electronic B2B Marketplaces with Different Ownership Structures." Management Science **53** (6): 952-961.
- Zhu, K. (2004). "Information Transparency of Business-to-Business Electronic Markets: A Game-Theoretic Analysis," Management Science **50**(5): 670-685.

Figure 2

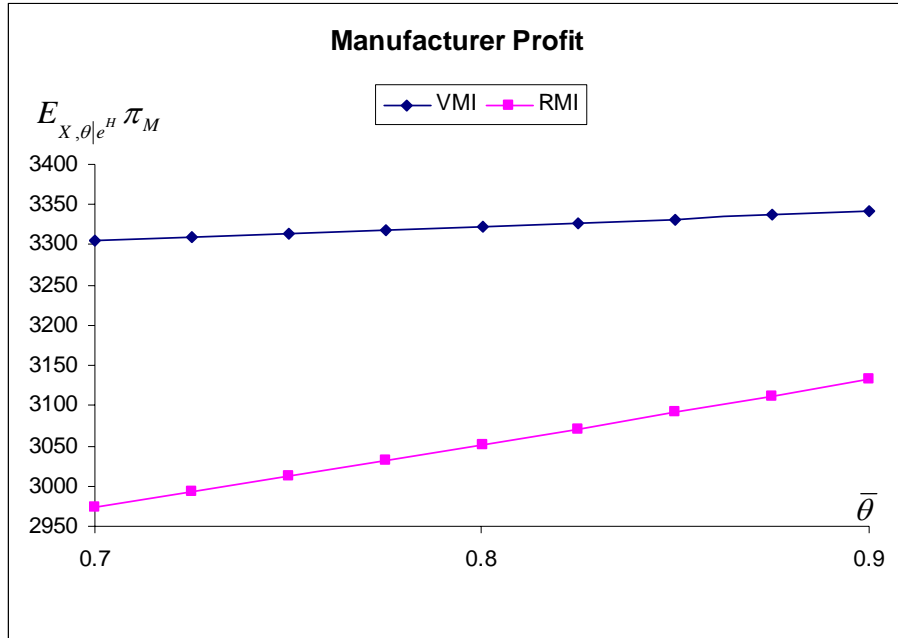


Figure 3

