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Control and enforcement in order to increase supplier inventory in a JIT contract

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ABSTRACT

Prompt response to customer demand has long been a point of major concern in supply chains. "Inventory wars" between suppliers and their customers are common, owing to cases in which one supply chain party attempts to decrease its stock at the expense of the other party. In order to ensure that suppliers meet their commitments to fulfill orders on time, customers must formulate incentives or, alternatively, enforce penalties. This paper deals with a customer organization that has a contract with a supplier, based on Just-In-Time strategy. Initiating a policy of sanctions, the customer becomes the lead player in a Stackelberg game and forces the supplier to hold inventory, which is made available to the customer in real-time. Using a class of sanctioning functions, we show that the customer can force the supplier to hold inventory up to some maximal value, rendering actual enforcement of sanctions unnecessary. However, contrary to expectations, escalation of the enforcement level can in fact reduce the capacity of the supplier to replenish on time. Consequently, the customer must sanction meticulously in order to receive his inventory on time. Having the possibility to devote a few hours each day to sanctioning activity significantly reduces the customer's expected cost. In particular, numerical examples show that the customer's costs under an enforcement level may be only 2 percent higher than his costs in a situation in which all inventory is necessarily replenished on time.

1. Introduction

Prompt response to customer demand has long been a point of major concern in supply chains and has given rise to such inventory management strategies as *Continuous Replenishment Program, Efficient Consumer Response, Just-In-Time (JIT) Supply, Ship-to-Order* and *Demand-Driven Supply* (see, for example, Barnes et al., 2000; Harris, Swatman, & Kurnia, 1999; Raghunathan & Yeh, 2001; Ayers, 2001). In the electronics industry, for example, original equipment manufacturers (OEMs) frequently contract out their manufacturing to electronics manufacturing services, and the latter are contractually obligated to meet the OEMs' demands on a continuous basis in a JIT mode, with little or no advance notice (Barnes et al., 2000). Intra-supply-chain competition constitutes a main barrier to the implementation of such inventory management approaches. Indeed, "inventory wars" between suppliers (e.g., manufacturers) and their customers (e.g., retailers) are a common occurrence, owing to cases in which one supply chain party attempts to decrease its stock at the expense of another party (Cachon, 2001). As a result of such competition, the likelihood of stockouts grows, and the replenishment lead-time becomes uncertain.

Management literature suggests various coordination approaches to overcome intra-supply-chain competition. These approaches are based on specially designed incentives, penalties and cost sharing. Grout and Christy (1999), for example, examine how a supplier, committed to a long-term contract with a customer based on a fixed selling price, responds to incentives for supplying JIT shipments on time, as well as to penalties for failure to fulfill demand on time. The authors show how increasing the incentive or penalties increases the inventory capacities that the supplier holds. If there is no incentive or, alternatively, the penalties are not enforced, the supplier is led to reduce his inventory capacities as well as his service level.

Vendor-managed inventories (VMI) are another successful approach to preventing the uncertain lead-times and low service levels associated with intra-supply-chain competition. With VMI, suppliers generate orders based on mutually agreed-upon objectives for inventory levels, fill rates and transaction costs, in addition to demand information sent by their distributor customers. The supplier shares the customer's inventory-related costs and monitors the inventory status information to make sure that the distributor customer always has the appropriate amount of stock on hand (see, for example, De Toni & Zamolo, 2005; Lee, So, & Tang, 2000; Vigtil, 2007; Yonghui & Raiesh, 2004 for deliberations on information sharing between parties employing VMI). It has been shown that, in promoting information sharing between the customer and the supplier, vendor-managed systems enable the customer (distributor) to lower his inventory

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levels, thereby leading to carrying-cost savings (Cachon & Fisher, 1997; Schenk & McInerny, 1998). Moreover, vendor-managed systems provide the supplier with flexibility in its production operations (Fry, Kapuscinski, & Olsen, 2001; Savaşaneril & Erkip, 2010). Given that the firms maintain their independence, however, they can exercise discretion over the extent of information sharing, which may have complex consequences. Notably, Lee et al. (2000) show that the supplier's on-hand inventory level may be affected by the level of information shared with the customer. In particular, the authors find that if the customer does not inform the supplier of the realized value of the demand in each period, the supplier ends up holding an inventory level that is almost two times greater than that under information sharing.

Another approach is to incentivize the supplier to increase its inventory level, thereby reducing the lead-times and the likelihood of stockouts on the customer's side. This approach is realized through so-called option contracts, in which the customer pays for the option to obtain additional supplies when needed. Specifically, in Wang and Liu (2007) the customer orders a basic level of inventory, and the supplier necessarily holds that level. In addition, the customer pays an option cost for every additional unit of inventory that the supplier chooses to hold for him. If, according to the realized demand, the customer needs to exercise an additional purchase of inventory, he pays an exercise cost. Consequently, it is in the supplier's interest to hold a greater level of inventory than that of the customer's basic order (see also Zhao, Wang, Cheng, Yang, & Huang, 2010). Fang and Whinston (2007) consider an option contract in which the supplier is dominant and sets the option and exercise costs. If a customer buys options in advance (before the demand is realized), he receives priority over other customers in receiving the inventory. The authors show that the inventory level that the supplier holds in this case is higher than that under no option contract.

In this paper we examine the case of a customer who employs the JIT management strategy when contracting with a supplier. The JIT management strategy implies that lead-times are short. The customer's goal is to set an optimal enforcement policy in order to prevent breach of contract by the supplier, and to minimize the associated costs.

Our study is motivated by a real-life supply chain involving the Israel Police (customer) and a supplier of security products. The arrangement between the customer and the supplier is based on a standard contract, according to which, at the beginning of each period, the customer sets an order quantity to be supplied and pays for the order. The supplier then ships the products over the course of the period in response to the customer's ongoing requests. When demand during a given period is lower than expected, the customer might not request that the entire order quantity be shipped during that period; in such a case, the supplier will still fulfill the entire prepaid order by the end of the period. Similarly, if, at any point in time over the course of the current period, the supplier does not have sufficient stock to fulfill a specific order, the unshipped quantity will be supplied by the end of the period.

A key point of concern in the scenario described is that inventory shortage can lead to deadly consequences. As a result, both the police (customer) and the supplier accumulate excessive inventories, thereby consuming vast resources. The large order quantities dealt with imply that high inventory costs are involved, even if the unit holding cost is not high. In order to reduce his own holding costs, the supplier attempts to reduce the quantity of stock he holds at any given time. This implies that the supplier ships steadily in response to the customer's requests (i.e., his shipment costs are not affected) but is not always able to completely fill the orders on time. As noted above, in cases in which the supplier lacks sufficient stock to fulfill an order, he ships the remaining quantity at the end of the period. This behavior induces the customer to hold greater stocks. To prevent the supplier from engaging in such behavior, the customer employs sanctions against the supplier when the latter does not provide timely shipments. The supplier is then charged by the purchasing department, which takes all the complaints into account and issues them in the form of a monetary charge to the supplier. Note that the customer imposes sanctions only on days in which it requests products (which have been paid for as part of the prepaid order made at the beginning of the current period) and the supplier is not able to ship the products on those same days. Enforcement of sanctions inflicts costs on the customer: the act of sanctioning is time-consuming and is carried out in addition to the standard logistic functions executed by customer's management department. Thus, the time invested in sanctioning, referred to as the *enforcement level*, is a decision variable. That is, the customer's effort level is measured with the time spent on sanction-related activities, which is a common practice. The customer's goal is to find the optimal trade-off between the total investment in sanctioning and the inventory holding cost.

We model the competition in the described two-echelon supply chain with a Stackelberg game such that the customer is the leader, whereas the supplier is the follower. Our results show that the customer can force the supplier to hold inventory up to some maximal value. This value depends on the total time that the customer can actually spend enforcing penalties on each day, on the rigorousness of the punishment toward the supplier due to not replenishing on time (see below), on the holding cost and on demand distribution. Moreover, we find that when the customer escalates the enforcement level, the supplier does not necessarily increase the inventory level that he holds throughout the period (and can thereby replenish on time) and may even reduce it.

The rest of this paper is organized as follows. Section 2 presents a description of the problem and the corresponding model. Section 3 describes the decision of the supplier (follower player) regarding the inventory level he holds for the customer. This decision is made in response to the decisions of the customer (leader player) about the order quantity and enforcement level; the customer's model is described in Section 4. Both Sections 3 and 4 include analytical models as well as numerical illustrations. Section 5 concludes the paper.

2. Problem formulation

We consider a multi-period two-echelon supply chain model consisting of one supplier and one customer. During each period, n, of τ days, the customer's inventory has to satisfy a total periodic demand of D_n. This demand is stochastic with realization d_n, probability density function $f_n(d_n)$ and cumulative distribution function $F_n(\cdot)$. As in many studies, including Khmelnitsky and Caramanis (1998), Kogan and Lou (2002) and Kogan and Tell (2009), the demand rate D_n/τ within a given period n is assumed to be constant. Let N be the total number of periods. At the beginning of each period n, before the demand is realized, the customer orders q_n units of inventory based on his initial inventory I_n. According to the contract, the supplier has to replenish that quantity of inventory over the course of period n, in shipments of quantities that correspond to the customer's needs. The supplier is a distributor or a wholesaler that can deliver in no time if his stocks are sufficient. Moreover, in the type of environment that we consider (i.e., a small country), distances are small, so the delivery process is quick and efficient. Therefore, we assume the supplier's lead time is negligible. On the other hand, it takes time to his subcontractors to manufacture and deliver the products. Therefore, the subcontractors' lead-time is not zero, that is, the supplier cannot wait until the last moment for the demand to realize as he might not be able to meet the demand and thus incur penalties. However, in an attempt to avoid holding costs, the supplier may choose not to hold the entire quantity q_n in his warehouse during the period and instead to hold only some fraction α_n of q_n. We refer to $\alpha_n q_n$ as the "held quantity" at period n. Thus, the quantity of inventory that is available for the customer during period n is $I_n + \alpha_n q_n$. The customer will necessarily receive the rest of the order, $(1-\alpha_n)q_n$, at the end of that period. On