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Vendor managed inventory with a capacitated manufacturer and multiple retailers: Retailer versus manufacturer leadership

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ABSTRACT

Considering a supply chain composed of a single capacitated manufacturer and multiple retailers, we model a Stackelberg game vendor managed inventory framework under two scenarios: in the first, we follow the traditional approach wherein the manufacturer is the leader; in the second, we let one of the retailers act as the dominant player of the supply chain. Is retailer dominance a preferred outcome by all retailers? Can the supply chain efficiency be improved by having the dominance gravitated from the manufacturer to one of the retailers? Solving the corresponding MINLP problems, we provide some insights using numerical examples.

1. Introduction

Reducing inventory levels of finished products is a major supply chain management challenge. Recent developments in information technology have facilitated the emergence of new cooperative supply chain contracts such as vendor managed inventory (VMI). VMI is an inventory management strategy whereby the upstream vendor manages the downstream retailers' inventories. It allows the vendor to gain access to inventory and market-related information of the retailers he supplies. This strategy is increasingly being adopted by retailers and their suppliers alike as it benefits both of them: the retailer can improve his fill rates and decrease inventory stockouts, while the supplier, by having access to the downstream market information, enjoys the benefits of better production planning. Additionally, VMI contracts make the downstream retailers sticky, in the sense that they are less likely to switch to a competitive supplier.

Examples of successful implementation of VMI strategies are abundant. For instance, Barilla, after adopting a VMI strategy, became the largest pasta manufacturer in the world in 1990. Other examples, include retailers such as Home Depot, Kmart, Dillard Department Stores, and JCPenney, who are often referred to as the early adopters of VMI strategies.

While the mainstream supply chain literature, in most instances, considers the upstream member of the supply chain as the leader, reality provides evidence that the retailers may, in fact, play a dominant role in the interaction between them. An example of such a powerful retailer is Wal-Mart, who continually exerts pressure on its suppliers to reduce their wholesale prices and improve delivery times. Messinger and Narasimhan (1995) provide a discussion on how the bargaining power has shifted to the retailers in the grocery channel. Modeling powerful retailers, i.e., the bargaining power shifts downstream, may result in different optimal decisions by the members of the supply chain than when the supply chain is lead by the manufacturer. Ertek and Griffen (2002) investigate the impact of shifting power from the manufacturer to the retailer on price structure and profits in a two stage supply chain.

The dominance of powerful retailers raises concerns about the optimality of previously derived results of VMI contracts. Namely, VMI contracts could be set off by retailers such as Wal-Mart and Home Depot, and then the supplying manufacturer could end up offering the *same* VMI contract to all its downstream retailers. Having the same VMI contract available for all retailers was assumed e.g. by Yang and Zhou (2006), Yuang et al. (2006), and Yu et al. (2009). Moreover, offering the same contract for all retailers is very useful in practice, because it can shield manufacturers from antitrust litigation under Robinson-Patman act (Iyer, 1998). Iyer (1998) shows that offering similar contracts to all the retailers is sufficient only in markets with substantial locational differentiation. To that end, we formulate the inventory decisions in the supply chain using a Stackelberg framework. We first consider the benchmark setting whereby the manufacturer is the leader and offer the same VMI contract to all retailers. Thereafter, we allow one of the retailers to act as the dominant retailer. This

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retailer sets forward the initial part of the VMI contract, which stands valid also for the VMI contract the manufacturer later offers to the remaining retailers.

The two scenarios are formulated as a two-stage mixed integer nonlinear problems for the leader and the followers, respectively. We transform these problems into a single nonlinear problem by adding the followers' responses into the leader optimization problem. We solve the general nonlinear problem using an appropriate solver and the results are illustrated through numerical examples. We find that the leader retailer enjoys the benefits of leadership in terms of higher profits and lower fraction of backlogging compared to the manufacturer leadership. Also, retailer leadership decreases the product wholesale price and consequently, the market price of the product, which is a plausible outcome for customers. We compare the supply chain overall efficiency when the manufacturer is the leader versus different settings for retailer leaders and we find that the overall efficiency of the supply chain increases as the leader retailer market scale decreases.

The rest of the paper is organized as follows: Section 2 reviews pertinent literature; Section 3 presents the VMI problem formulation; Section 4 studies the benchmark model with the manufacturer being the leader, while Section 5 considers the case of a powerful retailer; finally, Section 6 concludes.

2. Literature review

The literature on VMI-driven supply chains is fairly extensive. One body of this literature focuses on measuring the benefits of adopting this inventory cooperative strategy (e.g., Dong and Xu, 2002; Yao et al., 2007). Another part of the literature looks into the optimal decisions made by the members of the supply chain adopting a VMI contract. Woo et al. (2001), who consider a supply chain consisting of a single manufacturer and multiple buyers who face constant demand rates, investigate the joint Manufacturer and buyers investment amount and replenishment decisions in order to decrease the total cost. Zhang et al. (2007) extend Woo et al.'s (2001) work by relaxing the common replenishment cycle assumption and allow retailers' ordering cycles to differ from each other. In Lu (1995) the vendor (manufacturer) minimizes the total annual cost subject to the maximum cost that the buyer may be prepared to incur when the vendor knows the buyer's annual demand and previous order frequency. The author derives the optimal decisions for a one vendor one buyer supply chain and develops a heuristic algorithm for multiple buyers case. Disney and Towill (2002) apply APIOBPCS (Automatic Pipeline, Inventory and Order Based Production Control System) algorithm to a VMI supply chain and derive the stability conditions for the supply chain using this algorithm. Wong et al. (2009) consider a single supplier multiple retailers supply chain. They use a VMI setting to model the coordination in the supply chain when a sales rebate contract is used. They compare between two scenarios; independent retailers and competing retailers. They show that the supplier profits are higher under the competing retailers' scenario because the competition among the retailers will lower the prices of the product and hence, the overall demand increases.

While the previous mentioned works do not use a game theory approach, other works utilize a Stackelberg framework to formulate the coordination process in the supply chain. This methodology is widely used in the general supply chain setting. For example, Weng (1995) presents a supply chain that consists of a single manufacturer who offers quantity discounts and franchise fees to identical retailers. Viswanathan and Wang (2003) study different types of quantity discounts offered by a single manufacturer to a single retailer. Viswanathan and Piplani (2001) analyze a supply chain with multiple retailers and quantity discounts. They derive a solution methodology to find the common replenishment cycle and the discount price. Qin et al. (2007) consider volume discount and franchise fees as a coordination mechanism where the supplier is the leader in the supply chain. They show that profits are higher when demand is price sensitive. They also show that volume discount and franchise fee strategy results in higher profits when the demand is price sensitive. Munson and Rosenblatt (2001) propose a mechanism by which a company can coordinate its purchasing and production functions and create an integrated plan for a supplier–manufacturer–retailer supply chain. The output of their study is an integrated plan that dictates order and production quantities for the three firm supply chain. Savaskan et al. (2004) formulate the problem of choosing the appropriate reverse channel structure for the collection of used products from customers for a single manufacturer, which they utilize to find the optimal option out of three possible ones. Lau et al. (2007) relax the deterministic and symmetric-information in the manufacturer–retailer supply chain by considering a stochastic and asymmetric-information framework for a manufacturer leader in the supply chain.

In the VMI setting, there are some works that utilize a Stackelberg framework to formulate the VMI contract and the corresponding sequence of decisions when the manufacturer is the leader in the supply chain. Yuang et al. (2006) consider one manufacturer that manages the inventory for multiple retailers. They model inventory costs at the manufacturer side and at each retailers' side with including back ordering costs and production costs into the manufacturer problem. They develop the leader and followers optimization problems and suggest a closed form solution algorithm to solve the followers and leader problems. The solution algorithm proposed by Yuang et al. (2006) is limited to a small number of retailers and does not allow either of the followers or the leader problem to be non-convex. Yu et al. (2009) extend Yuang et al. (2006) work into a three-echelon supply chain. They use the same solution methodology and solve some numerical examples for the model. The authors argue that an improvement in the equilibrium solution can be achieved if the retailers are willing to sign a profit share contract with the manufacturer.

Using a game theoretical framework enables the investigation of leadership in the supply chain. Most of the research body in this literature assumes other contractual mechanisms. E.g., retailer leadership, in the general supply chain setting, is explored by Cachon and Zipkin (1999) who study the optimal inventory decisions for a two-stage supply chain with stationary stochastic demand and fixed transportation times. They also compare the supply chain decisions under both competitive and cooperative games, and investigate the supplier Stackelberg game against the retailer Stackelberg game. One major finding of their paper is that the Stackelberg retailer chooses a base stock level that is higher than in the supplier Stackelberg case. Lau and Lau (2005) suggest a stochastic and information-asymmetric Stackelberg game framework for a two-echelon supply chain under linear and iso-elastic demand curves. Ertek and Griffen (2002) explore the impact of power structure on price, sensitivity of market price, and profits in a two-stage supply chain that consists of a single supplier and a single buyer. They derive the pricing scheme when the supplier has dominant bargaining power versus the case where the buyer has a dominant bargaining power. Wang (2009) investigates a traditional supply chain arrangement versus a VMI arrangement for a single manufacturer single distributor supply chain where the manufacturer produces a single short life cycle product with random yield and uncertain demand. The author shows that the VMI arrangement is preferred by the manufacturer