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Contracting for vendor-managed inventory with consignment stock and stockout-cost sharing

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ABSTRACT

We examine the problem of designing a vendor-managed inventory (VMI) contract with consignment stock and stockout-cost sharing in a (Q, r) inventory system between a supplier and a retailer. In particular, the contract specifies fixed and proportional penalties charged to the supplier when stockouts occur at the retailer. The retailer chooses the penalties and offers the contract to the supplier, and the supplier can accept or reject the contract. If he accepts it, the supplier manages the inventory at the retailer and makes replenishment decisions. For the deterministic demand we characterize the optimal contract for the retailer and the corresponding optimal inventory policy for the supplier. Our computational study for the deterministic and stochastic demands provides several interesting results. In particular, it suggests that VMI may result in significant cost savings for both the retailer and the supplier, but that the retailer may not always benefit from VMI. Our study also sheds lights on the relationship between VMI and replenishment leadtime and the value of information sharing on the retailer's stockout quantity in VMI contracting.

1. Introduction

Vendor-managed inventory (VMI) is a well-known industry practice for supply chain collaboration, where the supplier manages inventory for the retailer (or manufacturer) and decides when and how much to replenish. VMI started as a pilot program in the retail industry between Wal-Mart and Proctor & Gamble (P&G) in the 1980s and has been adopted by many supply chains such as Dell, Barilla, Costco, and Campbell's Soup. VMI programs have resulted in significant savings of inventory costs, and the benefits of VMI are attributed to information sharing between supply chain partners, increased flexibility in the supplier's production and delivery plan (Fry et al., 2001; Savasaneril and Erkip, 2010), economies of scale in production and delivery (Bookbinder et al., 2010; Nagarajan and Rajagopalan, 2008), and freight consolidation when the supplier has VMI agreements with multiple retailers (Cetinkaya and Lee, 2000; Cheung and Lee, 2002; Zavanella and Zanoni, 2009).

In designing a VMI contract, an important issue is how to share inventory-related costs between the supplier and the retailer: Who will have the ownership of the inventory at the retailer? Who is responsible for physical storage costs such as rent, electricity and material handlings? How do they share stockout costs and fixed ordering costs? For example, consignment stock can be a part of the VMI contract, in which the supplier has the ownership of the inventory at the retailer, and stockout costs can be shared under VMI between the supplier and the retailer (Bichescu and Fry, 2009). Another important issue is how the retailer can induce the supplier to maintain the right level of inventory at the retailer. For example, the VMI contract can specify minimum and maximum inventory levels and penalties for under-stocking and over-stocking (Fry et al., 2001).

In this paper, we examine the problem of designing a VMI contract between a supplier and a retailer, focusing on how to share stockout costs. The contract specifies a fixed penalty and a proportional penalty that will be charged to the supplier when stockouts occur at the retailer. The fixed penalty is charged per replenishment cycle when stockouts occur in a cycle, and the proportional penalty is charged per backordered item per unit time. The contract also specifies that the inventory at the retailer is owned by the supplier (i.e., consignment stock) and that the retailer is responsible for physical storage costs. The retailer chooses the stockout penalties and offers the VMI contract to the supplier. The supplier can accept or reject the contract and, if he accepts it, he makes replenishment decisions under the contract.

Note that the form of the contract in our model may be viewed as a modified version of the (z, Z)-type contract examined by Fry et al. (2001). The (z, Z)-type contract specifies a minimum inventory level,

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z, and a maximum inventory level, Z, with proportional under- and over-stocking penalties. In our model we assume $z=0$ and $Z=\infty$, but propose a fixed stockout penalty in addition to a proportional stockout penalty. One of the reasons for introducing the fixed stockout penalty is because of a potential drawback of the proportional stockout penalty: One may argue that it might be hard for the supplier to gain the information on the number of units short at the retailer (i.e., the retailer's stockout quantity) and that the retailer might charge the supplier according to an unreal stockout quantity. One of the purposes of our research is to examine the value of information sharing on the retailer's stockout quantity by comparing the case where only the fixed stockout penalty is used with the case where the fixed and proportional stockout penalties are used.

We also note that consignment stock and VMI are two supply chain practices that can be used separately and that the traditional VMI and the VMI with consignment stock should be distinguished (see, e.g., Gumus et al. (2008)). In our VMI model, however, consignment stock is assumed to be a part of the VMI contract and, hence, the supplier incurs costs of capital for the inventory held at the retailer. Note that without consignment stock in our VMI model the supplier would push inventory to the retailer as much as possible to avoid stockout penalty costs and fixed replenishment costs. However, with consignment stock it may not be the best interest for the supplier to do so. In this paper we assume consignment stock as a part of the VMI contract and focus on the optimal choice of stockout penalties for the retailer.

We examine the above problem of designing a VMI contract in a continuous-review (Q, r) inventory system. In the traditional retailer-managed inventory (RMI) model, the retailer decides Q and r, and places an order of Q whenever the inventory position falls down to reorder point r. The retailer incurs inventory-holding costs, backorder-penalty costs, and fixed ordering costs. The supplier does not carry inventory, and incurs fixed costs of production and delivery. On the other hand, under the VMI contract, the supplier decides Q and r, and replenishes the retailer's inventory accordingly. The supplier incurs costs of capital for the inventory at the retailer, and fixed ordering costs as well as his own fixed costs of production and delivery. He pays the retailer the fixed and proportional penalties when stockouts occur at the retailer. The retailer incurs backorder-penalty costs and physical storage costs. The retailer (the supplier) minimizes her (his) expected long-run average total costs.

For the deterministic demand case, we characterize the optimal VMI contract for the retailer and the corresponding optimal replenishment policy for the supplier. Our computational study for both the deterministic and stochastic demand cases provides several interesting results. In particular, our results suggest that VMI may result in significant cost savings for both the retailer and the supplier, but that the retailer may not always benefit from VMI, especially when the ratio of the supplier's fixed cost to the retailer's is small and/or when the physical storage cost is relatively large compared with the cost of capital. Our computational study for the stochastic demand case also provides an interesting result on the relationship between VMI and replenishment leadtime. Our results indicate that the benefits of VMI to the supplier (retailer) may increase (decrease) as the replenishment leadtime shortens. Our results also suggest that the value of information sharing on the retailer's stockout quantity may be significant in VMI contracting.

The contributions of our paper are threefold: firstly, to our knowledge, our paper is the first that examines the problem of designing a VMI contract with stockout-cost sharing, in which the retailer charges fixed plus proportional stockout penalty costs to the supplier. Our model adds to the literature on VMI contract design. Secondly, although our model involves four decision variables (i.e., Q and r for the supplier and fixed and proportional stockout penalty costs for the retailer), we provide several analytical results for the deterministic demand case, which can be used for an efficient solution procedure when demand is deterministic. Thirdly, our computational study provides important managerial insights on the benefits of VMI, the relationship between VMI and replenishment leadtime, and the value of information sharing on the retailer's stockout quantity in VMI contracting.

2. Literature review

There exists a substantial amount of literature related to VMI. Most of the papers focus on examining the benefits of VMI in various settings, and some of them study the problem of designing VMI contracts. In what follows we review the papers that are closely related with our paper and then some of the most recent papers on VMI.

Fry et al. (2001) develop a production/delivery model with base-stock inventory policies and examine the benefits of VMI due to better coordination of production and delivery under a (z, Z)-type VMI contract with penalties for under- and over-stocking, where z is a minimum inventory level and Z a maximum inventory level. They also provide some guidelines in choosing the optimal contract parameter values for the retailer through analytical and numerical studies. As mentioned in the above, the form of VMI contract in our model may be viewed as a modified (z, Z)-type contract with $z=0$ and $Z=\infty$ but with two types of under-stocking penalties: fixed and proportional.

Nagarajan and Rajagopalan (2008) consider a business scenario in which both a supplier and a retailer incur stockout costs when stockouts occur at the retailer. They examine a holding cost subsidy-type VMI contract where the retailer charges the supplier a holding cost based on average inventory at the retailer. They examine this contract using the EOQ model and approximate cost formulations of the continuous-review and periodic-review inventory models. Our paper is similar to theirs in that we also examine the problem of designing a VMI contract in an inventory system with fixed costs, where the benefits of VMI are due to economies of scale in production and delivery. However, we consider a different scenario in which the supplier incurs little or no direct cost when there is a stockout at the retailer, and examine a VMI contract in which the retailer charges penalties to the supplier when stockouts occur at the retailer. We examine this problem by using an exact cost formulation of the continuous-review (Q, r) inventory model.

Bichescu and Fry (2009) examine the effect of channel power on VMI performance in a (Q, r) inventory system with a VMI agreement in which the supplier chooses order quantity Q and the retailer chooses reorder point r. In their model the backorder-penalty costs are split between the supplier and the retailer, but how to split them is a given parameter, rather than a decision variable. Guan and Zhao (2010) examine a revenue sharing contract with consignment stock and a franchising contract in a (Q, r) inventory system. In the revenue sharing contract with consignment stock, the supplier owns the inventory at the retailer but the retailer shares a percentage of sales revenue with the supplier, and the contract is settled down through a bargaining game between the two parties with the supplier initiating the bargaining process. In the franchising contract scenario, the retailer owns her inventory and initiates the bargaining process to determine the franchise fee and the inventory policy. In their model the preference of each party over inventory policy is independent of the revenue sharing proportion or the franchise fee.

We now briefly review some of the most recent papers on VMI. Several recent papers examine the benefits of VMI in various