



## Channel coordination under consignment and vendor-managed inventory in a distribution system

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### ABSTRACT

This paper deals with the problem of coordinating a vertically separated distribution system under vendor-managed inventory and consignment arrangements. We formulate the profit-maximization problem and carry out equilibrium analysis under cooperative and non-cooperative settings. In addition, a revenue-sharing scheme joint with a side-payment is proposed, which leads to Pareto improvements among channel participants. Our analysis reveals that the non-cooperative decentralization tends to price higher and stock less, which leads to a lower channel-wide profit. The consistent bias can be rectified by the dominant, cooperative wholesaler or by using the proposed two-part revenue-sharing mechanism.

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### 1. Introduction

Coordinating upstream vendors and downstream buyers is challenging in a decentralized supply chain, where each firm separately maximizes its own profit. One of the prominent coordination mechanisms is to streamlining the workflow and decision-making processes through vendor-managed inventory (VMI) with consignment arrangement in a vertically separated channel. Such business arrangement is widely adopted in the on-line commerce, e.g., Amazon's warehouses and their millions of affiliated vendors, and the brick-and-mortar retailing as well. Sara Lee Corporation's consignment marketing channel for its L'eggs pantyhose (Coughlan et al., 2001) and supermarkets and convenience stores selling the direct store delivery products, e.g., dairy, beverage, bakery, etc. (Turcsik, 2002) are some of the examples in retailing with consignment arrangement. Other examples can be found in vending machine services in the soft drink industry (Ong et al., 1996), second-hand textbooks resale in the bookstores (Bolen, 1988), and parts supply in the assembly systems in the aircraft, personal computer, and automobile industries (Gerchak and Wang, 2004; Micheau, 2005).

In addition to the widespread practices in academic literature, our research was motivated by the VMI partnerships between a regional seafood vendor and a local retail chain. After on-site visit and interview with one of the store managers, we found their supply chain practice and distribution network of greater amberjack for sliced raw fishes, i.e., sashimi for short, fit well into our problem. The vendor distributes a wide variety of sashimi to local restaurants and retail stores under VMI with consignment arrangement. To remain fresh, the fishes are shipped twice a day, at vendor's expense, in a tightly sealed plastic bag of a freezer. After receipt by the store, they are displayed in the refrigerated showcase for merchandising; while the title of the good is still owned by the vendor. For each item sold, the store deducts a percentage from the selling price and remits the balance to the vendor. It is well documented that such scan-based trading (SBT) can increase sales and reduce

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inventory. The SBT partnership between six Meijer stores and Smith Dairy has resulted in a 6% increase in sale and more than a 50% reduction in the on-hand inventory (Gentry, 2006).

This paper studies how VMI joint with consignment alters the performance of a vertically separated distribution system with one wholesaler and multiple retailers, i.e., the profit gained by the channel participants who adopt such an arrangement. We formulate the decision-making of the two-echelon system as profit-maximization models. Equilibrium analyses are carried out under the non-cooperative and cooperative settings with considering three kinds of contractual arrangements: the wholesale-price-only, VMI, and VMI with consignment contracts. Equilibrium analysis can well describe the behavior of supply, demand, and price in the underlying distribution system. It seeks to prove that equilibrium price and quantity for goods exist in the system. Under a game-theoretical setting, the dominant wholesaler can act cooperatively or non-cooperatively. For a cooperative wholesaler, it can induce the retailers to response with a channel-wide optimal decision, e.g., setting a lower retail price, by taking a channel-wide optimal action, e.g., choosing a higher stock level. In contrast, a non-cooperative wholesaler takes action by optimizing its own profit without considering its counterpart reactions and channel-wide benefits.

The problem being considered in the paper is unique in the sense that we incorporate both effects of decay or shrinkage loss and demand-stimulating inventory into account. The items displayed in the shelf-space or deposited in the warehouse are subject to depletion by phenomena other than demand; that is, through spoilage, shrinkage, decay, and obsolescence. In the retail industry, for example, inventory loss due to shrinkage—a combination of employee theft, shoplifting, administrative error, and vendor fraud, amounts to 1.7% of annual sales, which is equivalent to 31.3 billion dollars (Nation Retail Security Survey, 2003; Pavia, 2003). A recent survey reveals that the inventory loss in the US retailing has remained persistently high over the past 15 years, fluctuating between 1.54% and 1.95% of sales (Beck and Peacock, 2007). An empirical examination of nearly 370 000 inventory records from 37 stores of one retail chain shows that nearly two-thirds of the records are inaccurate (DeHoratius and Raman, 2008). In our seafood vendor-retailer system, the highly perishable greater amberjack fits well into our shrinkage assumption.

In the wholesaler-retailer system, the inventory-level or shelf-space effects appear especially crucial in store merchandizing. Goods are more likely to be selected when they get more shelf space with facing. Therefore, if a product is given a higher stock level, it is likely to be visually perceived, sorted out, and bought more frequently (Desmet and Renaudin, 1998; Kotzan and Evanson, 1969). The investigation by Koschat (2008) reveals that higher inventory-level has a significant effect on demand in the US magazine retailing. He suggested two mechanisms by which inventory-level might impact demand: the signaling effect and the effect of inventory on the number of product facing in the store. In the seafood merchandizing, the sashimi displaced in the refrigerated showcase may have both stimulating effects on customers' buying behaviors.

We incorporate such stimulating effects into the demand function. Based on our demand model and channel settings, the wholesale-price-only contract in a non-cooperative decentralization is derived and served as a benchmark, followed by analyzing the VMI with and without consignment contracts under a cooperative setting. In addition, the consigned VMI operated by a non-cooperative wholesaler is also under analysis. It is intuitive that the non-cooperative decentralization performs no better than the cooperative, so the question is whether it performs well under certain conditions. It is also important to assess whether the profit gains due to the cooperative is significant and whether it persists in consistent tendencies, e.g., setting higher or lower retail price and choosing higher or lower stock level. We also propose a two-part contractual arrangement that consists of a revenue-sharing percentage and an up-front lump-sum side-payment from the wholesaler to the retailers, i.e., the slotting allowances or slotting fees in marketing context (Bloom et al., 2000). The proposed scheme leads to channel coordination and Pareto improvements among channel participants, i.e., one party is better-off and the other is no worse-off.

The term of slotting fees describes a family of marketing practices that involve a lump-sum payment by the upstream wholesaler or manufacturers to persuade downstream retailers to stock, display, and support new products. Two schools of thought currently dominate the debate on slotting fees: the efficiency school and the market power school (Bloom et al., 2000). We attempt to lend some clarity to this debate from a channel coordination perspective. Our analysis tends to support the efficiency school, i.e., it improves channel efficiency by generating higher channel profits, and stimulates competition by setting a lower retail price. Besides, the geography of the efficient frontier (Harrison et al., 2003) is constructed to illustrate the feasible region of Pareto improvements from the channel-wide aspect.

In what follows, literature review is given in Section 2. The base model with a wholesale-price-only contract is derived in Section 3, and VMI with and without consignment under a cooperative setting are given in Section 4. Section 5 considers a non-cooperative wholesaler under VMI with consignment arrangement. Numerical study, two Pareto improving mechanisms, and sensitivity analysis are provided in Section 6. Section 7 concludes by summarizing our research contributions and providing future research directions.

## 2. Literature review

Since our study embraces several related yet rather disjoint research streams, namely the inventory and distribution system with shelf-space dependent demand, channel coordination with vendor-managed inventory, and consignment (revenue-sharing), we provide a brief review on each stream hereafter.

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