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Coordinating price and service level decisions for a supply chain with deteriorating item under vendor managed inventory

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ABSTRACT

This paper develops a Stackelberg game model of a one-supplier and one-retailer supply chain with deteriorating product to investigate how to coordinate the price and service level decisions under vendor-managed inventory (VMI) and examine system efficiency. We study the equilibrium price and service level decisions under the decentralized setting and the centralized setting, respectively; and design a generalized revenue-sharing mechanism to coordinate the supply chain. We find that the interaction between the retail price and the service level may invert the effect of deterioration rate on the retail price. The system efficiency of decentralized supply chain increases with market scale, price sensitivity, deterioration rate, the supplier's cost (including unit production cost, holding cost, and deterioration cost), and service investment efficiency, while decreases with production rate. In addition, we find that VMI may invert the effect of deterioration rate on the unit wholesale price of the decentralized supply chain; in the coordinated setting, the retailer should pay a higher transfer price to the supplier with VMI than that without VMI, the transfer price decreases with service investment efficiency, and higher service investment efficiency shrinks the transfer price difference.

1. Introduction

In reality, some inventory items or products such as electronic components, meat, vegetables, fruit, and flowers, often deteriorate over time (Li et al., 2010). For deteriorating products, a supplier (manufacturer) has to produce more products than the market demand because a part of the products will be deteriorated. The deterioration of products affects the supplier's production planning and inventory management, which in turn influences the retailer's decision. The retailer must consider the deterioration of products when making the decisions. Thus, the inventory model of deteriorating items gradually becomes an interesting and significant subset of supply chain management. For deteriorating items, one of the challenges is how to reduce the deterioration cost for deteriorated product, production cost, and holding cost. The integrated policy may result in a significant cost reduction when it is compared with the decentralized setting (Yang and Wee, 2003). In particular, vendor managed inventory (VMI) can improve the inventory management performance of a decentralized supply chain (i.e., reduce mismatching between supply and demand). Service level influences the purchase choice of consumer. A higher service level attracts more consumers to buy the products. However, increasing service level incurs a higher service cost. Thus, the retailer should jointly make the price and service level decisions to maximize the profit. In this paper, we focus on how to coordinate the price and service level decisions for a decentralized supply chain with deteriorating item under VMI and the effect of the interaction between the retail price and service level decisions.

Under VMI strategy, the supplier manages the retailer's inventory and makes the replenishment decision for the retailer. The supplier has an opportunity to organize the production and distribution process according to the actual demand. Nowadays many firms in different industries increasingly consider VMI as a strategic option to reduce cost and enhance their core competencies. For example, recently Samsung and Sony carried out VMI with Suning to build a new cooperation mode. And with VMI, DH Corporation and his distributor increased sales and their inventory levels are decreased. Point Spring and Driveshaft Company (PSD) improved inventory efficiency with VMI. VMI has become popular in high-tech industries, say, Dell and HP increased their performances through using VMI to reduce inventory levels and costs (Tyan and Wee, 2003).

Under VMI, although the supplier and the retailer collaborate in inventory management, they make the price and service level decisions independently, e.g. Samsung and Suning. Owing to double marginalization effect, the decentralized supply chain is not coordinated, which decreases the channel profit. Much of the supply chain management literature focuses on how to design a contract to achieve supply chain coordination and various types of

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coordination schemes are proposed (Cachon, 2003). Revenue-sharing scheme is often used to regulate the relationship among the members of supply chain. However, the traditional revenue-sharing contract cannot coordinate the supply chain with service investment and deterioration cost (Cachon and Lariviere, 2005). In this paper, we focus on how to design a generalized revenue-sharing contract to coordinate the supply chain and investigate how VMI affects the coordination mechanism.

This paper develops a Stackelberg game model of a supply chain consisting of one supplier and one retailer to investigate system efficiency, coordination of the decentralized supply chain under VMI and the effect of the interaction between the price and service level decisions on equilibrium outcome, where demand is sensitive to price and service level. The supplier produces a deteriorating item and manages the inventories at the own and retailer's sides. The two players maximize their long-term average profits. We first consider the decentralized supply chain, and then study the centralized system. We focus on the system efficiency of decentralized supply chain relative to the centralized system and how to coordinate it via a generalized revenue-sharing contract. We illustrate how the system efficiency depends on parameters. Some interesting managerial insights are generalized, say, a higher deterioration rate decreases the motivation of the players to coordinate their behavior because it raises the system efficiency. We also consider the case where the two players manage their inventories individually (i.e., without VMI). We compare it with the VMI setting to examine the effects of VMI on wholesale price and coordination mechanism. We find that with VMI, the retailer should pay a higher transfer price to the supplier than that without VMI. We illustrate the effects of the main factors including market scale, deterioration rate, the retailer's unit holding cost, and the service investment efficiency on the transfer prices under the two settings.

The remainder of this paper is organized as follows. The related literature is reviewed in Section 2. Section 3 presents the basic model and analyzes the equilibrium outcome of the decentralized supply chain. Section 4 investigates how to coordinate the supply chain via a generalized revenue-sharing contract and examines the efficiency of decentralized system. Section 5 explores the effects of VMI on wholesale price, and coordination mechanism. Section 6 summarizes the results and indicates directions for future research.

2. Literature review

This paper studies a VMI model of a supply chain with deteriorating item, which involves three streams of literature: deteriorating inventory model, VMI, and revenue-sharing contract. We review them in turn.

2.1. Inventory model of deteriorating item

Inventory management of deteriorating item is becoming more and more important as deterioration often occurs in reality. Ghare and Schrader (1963) developed an inventory model under constant demand with exponential decay and considered the effect of decay on inventory. Many researchers extended their model from the perspectives such as deterioration pattern (Wang et al., 2011), demand function (Balkhi and Benkherouf, 2004; Cheng and Wang, 2009), and backorder policy (Hsu et al., 2007). Wang et al. (2011) have used time-sensitive rate to model item decay. Hsu et al. (2006, 2007) focused on deteriorating items with expiration dates. Teng et al. (2002) considered the inventory model with lost-sales cost and non-constant purchase cost. Rau et al. (2003) developed a multi-echelon inventory model for a deteriorating item to study the optimal joint total cost (including the costs for the supplier, the producer, and the buyer) from an integrated perspective. Yang and Wee (2003) considered multi-item production lot sizing for deteriorating items. Chung and Huang (2007) developed an inventory model of a single deteriorating item with storage constraint under two-level trade credit to study the optimal retailer's ordering policy. He et al. (2010) considered the production and inventory planning of a manufacturer who produces some deteriorating products and sells them in markets with different selling seasons. Lin et al. (2010) examined four scenarios for cooperative relationships between the supplier and the retailer and found that information sharing plays an important role in reaching a win–win position. The above literature assumed that price is exogenous. Most of the deteriorating inventory models with endogenous price only considered the inventory management of a single firm (Teng and Chang, 2005; Dye, 2007). Tsao and Sheen (2008) considered the dynamic decisions on pricing, promotion, and replenishment for a retailer given the supplier's trade credit and examined the effect of the credit policy on the retailer behavior. Li et al. (2010) reviewed some deteriorating inventory models. Widyadana and Wee (2012) studied an economic production quantity model for deteriorating items with rework. Musa and Sani (2012) studied inventory management of deteriorating items that do not start deteriorating immediately. Wang et al. (2012) considered the consignment inventory policy with buyer's warehouse capacity constraint. Unlike the above literature, we consider the production planning and inventory management of a decentralized supply chain with endogenous prices and service level; and focus on the effects of the interaction between the supplier and the retailer, and the interaction between price and service level decisions on equilibrium outcome.

2.2. Vendor managed inventory

The VMI literature can be roughly grouped into two streams: one takes VMI as a given structure and studies the benefits from implementation; and the other focuses on the issues related to the structural design of VMI. The first stream suggested that VMI provides positive benefits to supply chain participants by reducing inventory cost (Zhang et al., 2007), and by reducing bullwhip effect, or by being better able to plan production, time distribution, and replenishment (Aviv, 2002; Disney and Towill, 2003; Yao et al., 2007). For the second stream, Kraiselburd et al. (2004) found that VMI performs better than traditional retailer managed inventory when manufacturer effort is a substantial driver of consumer demand and when consumers are unlikely to substitute other products. Wong et al. (2009) showed how to coordinate supply chain with sales rebate under VMI. Yao et al. (2010) studied how an incentive contract can be used to improve the benefits of the players under VMI. In this paper, we consider the two cases with and without VMI. We focus on the price and service level decisions of supply chain under VMI and the effect of VMI on the coordination mechanism.

2.3. Revenue-sharing contract

There is extensive literature on supply chain coordination management (Sahin and Robinson, 2002; Cachon, 2003). Here we only review revenue-sharing contract that is adopted by this paper. Revenue-sharing scheme was extensively adopted to improve the profitability of decentralized system (Gerchak and Wang, 2004). Wang et al. (2004) showed that under revenue-sharing contract, demand price elasticity and the retailer's share of channel cost are two key factors for channel profitability and the profitability of individual firms. Cachon and Lariviere (2005) studied the merits of revenue-sharing contracts relative to