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Dynamic supply chain coordination under consignment and vendor-managed inventory in retailer-centric B2B electronic markets

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ABSTRACT

This study examines the dynamic performance of vertically decentralized two-echelon channel coordination for deteriorating goods under consignment and vendor-managed inventory (VMI) contracts with revenue sharing from retailer-centric business-to-business transactions in both traditional markets and electronic markets (EMs). The research presents the profit-maximization problem and devises a method for making cross-enterprise dynamic joint decisions by combining calculus with dynamic programming for a retailer-led Stackelberg supply chain under cooperative and non-cooperative game settings over a multi-period planning horizon. The applicability of the proposed model is assessed using a case study involving a highly perishable product, sliced raw fish, in a supply chain comprising a regional seafood supplier and a local store belonging to a large national retail chain. The analytical results show that, in a cooperative setting, the EM with a consigned revenue-sharing VMI contract tends to achieve lower retail prices, larger stock quantity, improved channel efficiency, and increases in both retailer and supplier profits through an additional one-part tariff. Additionally, consumers benefit from lower retail prices and society benefits from increased overall channel profits in the cooperative channel and EM.

1. Introduction

Intensifying industrial competition and growing deployment of advanced information science and technology has prompted upstream and downstream entities to reorganize their supply chains to enhance efficiency and synergy through collaboration. However, coordinating and managing upstream suppliers and downstream buyers is challenging in vertically decentralized supply chains because participant decisions are based on different variables and ignore the profits or actions of other channel participants (Jeuland & Shugan, 1983). Effective coordination and cooperation in participant decisions is essential to achieve satisfactory results. For example, in the supplier–retailer–consumer channel, retail prices are higher if decisions of non-cooperative decentralized channel participants are made in a game-theoretical setting than if they are made cooperatively. Furthermore, the resulting decrease in stock level reduces overall channel profit. Additionally, supply chains are dynamic systems that evolve with changing customer demand and supply chain relationships. Even if demand is known, the planning process must still consider how changes in prices, trends, promotions, and other factors influence demand and cost parameters (Simchi-Levi, Kaminsky, & Simchi-Levi, 2008). Nevertheless, most enterprises realize that effective supply chain management (SCM) can increase profits by optimizing supply chain coordination and cooperation. Effective SCM requires approaches for efficiently managing and interconnecting dynamic and complex supply and demand networks from the end user through retailers, wholesalers, manufacturers and suppliers to optimize time, quantity and price in production and distribution. The objectives are increasing customer value and maximizing profits for both individual participants and the overall channel (Ganesan, George, Jap, Palmatier, & Weitz, 2009; Harland, 1996; Hines, 2004; Jeuland & Shugan, 1983).

In a vertically decentralized supply chain, the vendor-managed inventory (VMI) system with revenue-sharing consignment contract streamlines decision-making processes and flows of goods and information. This business model is widely used in various industries, including personal computers, sports equipment, automobiles, clothing, furniture, firearms, music, tools and antiques. Another application is B2B online commerce, such as Amazon and their numerous third-party affiliated suppliers, as well as America Online and their small- and medium-size businesses, which sell consumer goods via the Internet (Wang, Jiang, & Shen, 2004; Wingfield & Angwin, 2002). Other applications include supply chains for providing parts to aircraft manufacturers (Micheau, 2005), food to supermarkets (Turcsik, 2002), and second-hand textbooks to bookstores (Bolen, 1988). Taking a different focus to most of the academic literature, this study assessed a VMI and consignment scheme with revenue sharing involving a regional seafood supplier and a local store of a large national retail chain. This study found that the procurement of highly perishable raw fish slices (namely sashimi) provides a good example of a supply chain system under consigned VMI arrangement with revenue sharing.

Information technology (IT) is increasingly recognized as an important enabler of supply chain performance. Numerous studies agree

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that business processes and IT systems help enterprises outperform competitors (Simchi-Levi et al., 2008). Electronic markets (EMs) are attracting growing interest in the research on IT. Owing to technological advances, trade is increasingly conducted online in EMs rather than traditional markets (TMs). This study examines how a coordination scheme and transaction market influence the performance of a vertically decentralized dynamic channel system involving a retailer (i.e. Stackelberg leader) and a supplier working under a consigned VMI agreement with revenue sharing.

Decision making in the two-echelon system sees to maximize profit. Equilibrium analyses are performed in both non-cooperative and cooperative settings, and in both TM and EM offering business-to-business transaction services. Equilibrium analysis describes the dynamic behavior of price, scheduling/quantity and revenue-sharing percentage allocation for the sale of deteriorating goods from the supply chain system. In a game-theory setting, the dominant retailer acts cooperatively and non-cooperatively in TMs and EMs, respectively. A cooperative retailer can induce their supplier to optimize the overall channel via channel-wide optimal actions, such as selecting increasing stock levels. In contrast, non-cooperative retailers selfishly optimize their own profit without considering the consequences for their counterparts or overall channel benefits. The applicability of the proposed model is evaluated using a case study involving a highly perishable product in a supply chain under a revenue-sharing VMI and consignment program.

The considered problem is unique because it involves both jointly dynamic behavior (i.e. price sensitive and time-varying demand) and deterioration (i.e. shrinkage loss). By affecting demand, progressive companies naturally use pricing as an important lever in supply chain operations. For example, supermarket chains achieve price flexibility by frequently changing prices. In the largest U.S. supermarket chains, the number of weekly price changes ranges from 3223 to 4316, and an average of 15.66% of products experience price changes weekly (Levy, Bergen, Dutta, & Venable, 1997). Pashigian and Bowen (1991) showed that both sales frequency and percentage markups on fashion goods have increased since 1970. For less fashion-driven products, such as automobiles, in-season price reductions are common (Pashigian, Bowen, & Gould, 1995). Moreover, the airline industry routinely uses fare changes to manipulate demand (McGill & van Ryzin, 1999). In the electronic commerce (e-commerce) context, on-line retailers adjust their prices more readily than conventional retailers in response to structural changes in supply or demand (Brynjolfsson & Smith, 2000). According to the data and model assumptions in Federgruen and Heching (1999), dynamic pricing can increase profits by 2 to 6%, representing a substantial increase in low profit margin industries such as retail and computer manufacturing. The study examines the problem of dynamic joint decisions under various channel coordinating policies for deteriorating goods in B2B markets over a multi-period planning horizon.

In practice, numerous inventory items suffer deterioration, including agricultural products, drugs, fashion goods and high-tech products, which are subject to depletion by non-demand phenomena, such as scrapping, shrinkage and decay. Deteriorating inventory problems have recently attracted intensive study. For example, a National Accounting Association survey showed that, in all industries and product types, unreported scrapping is the major cause of inventory loss (Newton, 1988). Another survey revealed inaccuracies in almost two-thirds of 370,000 inventory records obtained for a large retail chain (DeHoratius & Raman, 2008). In the United States retail sector, inventory losses from shrinkage have remained high for the past 15 years, and totaled 1.59% of sales in 2006 (Beck & Peacock, 2007). These phenomena of deterioration are common and merit intensive study. In the seafood supplier–retailer system considered in this study, the highly perishable greater amberjack fish confirms the assumption of product deterioration.

This study considers the dynamic characteristics and deteriorating effects outlined above in supply chain analysis. Based on the demand function and channel settings used here, the consigned VMI system operated by a non-cooperative retailer in a TM serves as a benchmark to analyze non-cooperation in an EM. This study also analyzes the consigned VMI operated by a cooperative retailer in both TM and EM (Fig. 1). Intuitively, a non-cooperative decentralized channel in a TM should not outperform a cooperative channel in an EM. Therefore, the question is whether the profit gains of a cooperative EM are significant, and whether they result in consistent tendencies, such as lower retail prices and higher stock levels. This study also proposes a two-part contractual arrangement that includes both revenue sharing and lump-sum payments (i.e. slotting fees) from the supplier to the retailer. The proposed scheme achieves Pareto improvements and channel coordination between channel participants, that is one party is made better off but neither becomes worse off. Slotting fees are a marketing practice in which upstream suppliers make up-front lump-sum payments to incentivize downstream retailers to stock, display and support the products they wish to sell. Two schools dominate the argument regarding slotting fees: the efficiency school and the market power school (Bloom, Gundlach, & Cannon, 2000; Chen, Lin, & Cheng, 2010). This study considers this argument from the channel coordination and market perspectives. The analytical results of this study support the efficiency school; that is, slotting fees enhance channel efficiency by increasing overall channel profits, and achieve Pareto improvements by reducing retail prices and increasing stock levels.

The rest of this paper is organized as follows. Section 2 briefly reviews the theoretical background and presents three propositions. Section 3 then describes the problem context and develops mathematical models and solution procedures for two-echelon decentralized channels for use in non-cooperative and cooperative TM and EM settings. Section 4 then compares the solutions generated for the four policies and conducts sensitivity analysis of key parameters. Finally, Section 5 presents research findings, managerial implications, limitations and proposed future study directions.

2. Theoretical background

2.1. Channel relationship management

In a conventional supply chain, each link focuses on its own benefit and acts with little regard to other channel partners. However, fiercely competitive global markets, short product lifecycles and rising customer expectations are forcing enterprises to cooperate to enhance supply chain synergy. The rise of SCM has switched the focus of management from internal to external connections. Strategic partnerships between buyers and suppliers are essential to effective SCM. Channel structure and cross-enterprise coordination in a vertically separated channel have generated strong interest in numerous fields, and the recent marketing, economic, and management literature has intensively studied related issues (Benton & Park, 1996; Cachon, 2003; Choi, 1991, 1996; Coughlan, 1985; Jeuland & Shugan, 1983, 1988a, 1988b, 2008; McGuire & Staelin, 1983; Moorthy, 2005; Pasternack, 1985; Tsay, Nahmias, & Agrawal, 1999).

In a conventional supply chain, marketing and production organizations in a vertical channel are managed separately. Channel participants no longer generate manufacturing and retail plans independently, but instead cooperate to increase synergies by coordinating the entire channel for the benefit of all channel participants, that is they seek a situation that increases profits both for the channel as a whole and for each participant. The benefits of cooperation between upstream and downstream supply chain members include cutting costs, reducing capital investments, sharing risk, increasing agility and adaptability, focusing on core competencies, increasing profits, and reaping other tangible and intangible benefits (Ganesan et al., 2009; Lee, 2004). Shapiro (1977) and Kirby (2003) argued that adversary companies have enormous potential for both cooperation and conflict. However, such conflicts can be