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# Optimal dynamic policies for integrated production and marketing planning in business-to-business marketplaces

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ABSTRACT

This work develops optimal dynamic policies for integrated production and marketing planning in a vertically decentralized single-manufacturer and single-retailer channel over a multi-period planning horizon, subject to deteriorating goods and a multivariate demand function. This work formulates the discount profit maximization problem, and provides inter-enterprise dynamic joint decisions for retail price and replenishment schedule/quantity using a calculus-based formulation combined with dynamic programming. Additionally, two alternatives for doing business, namely, retailer-managed inventory with a price-only contract and vendor-managed inventory (VMI) with a consignment contract, are applied to business-to-business traditional marketplaces (TMs) and electronic marketplaces (EMs), respectively. Numerical results demonstrate that solutions generated in EMs outperform those in TMs in terms of maximizing channel-wide total discount profits and those of manufacturer and retailer. Further, analytical results show that the proposed policy under VMI with a consignment contract in EMs significantly increases system efficiency and simultaneously achieves Pareto improvements using an extra one-part tariff for the decentralized channel.



## 1. Introduction

Information technology (IT) has become increasingly important in enhancing supply chain performance in highly competitive global markets. Electronically enabled supply chains have the potential to improve supply chain performance, including increasing coordination effectiveness and transaction efficiency, by altering the quantity and velocity of information flows among supply chain partners (Chopra and Meindl, 2001; McAfee, 2002; Liu et al., 2005; Sanders, 2008). Swaminathan and Tayur (2003) demonstrated that an important link exists between an IT strategy, business processes, and supply chain performance. Indeed, effective supply chain management (SCM) requires collaboration among business processes and the integration of IT systems. Numerous studies have shown that enterprises applying business processes and IT systems outperform their competitors (Simchi-Levi et al., 2008; Qrunfleh and Tarafdar, 2014). In addition to increasing operational efficiency, a highly integrated system can strengthen strategic advantages and generate related benefits (Stefanou, 2001; Mandal and Gunasekaran, 2002; Fin, 2006; Wong et al., 2014).

An important building block in effective supply chain strategies is strategic partnerships between suppliers and buyers. The benefits of inter-organizational collaboration and cooperation between upstream and downstream supply chain entities include reduced costs, reduced capital investment, reduced pooling risk, increased agility and adaptability, improved customer service, enhanced profit margins, and a focus on core competencies (Stank et al., 1999; Lee, 2000; Quinn, 2000; Vickery et al., 2003; Arshinder et al., 2008; Chou and Chang, 2008; Chen and Wei, 2012; Chen, 2013; Sarker, 2013; Wu et al., 2014). One primary coordination task is to streamline business flows of goods and information and decision-making processes among channel partners using vendor-managed inventory (VMI) for a vertically decentralized channel (Disney and Towill, 2003). Strategic partnerships alter the ways in which information is shared and inventory is managed in a supply chain, potentially eliminating the bullwhip effect (Moinzadeh, 2002; Reddy and Rajendran, 2005; Yu et al., 2008, 2010). For example, Milliken & Company works with several clothing suppliers and retailers, all of which agree to use point-of-sale data from department stores to synchronize ordering and manufacturing activities. The lead time from ordering fabric to receipt of finished goods by the department stores was reduced from 18 to 3 weeks (Schonberger, 1996). The most important requirement for an effective supply chain partnership, especially one moving toward the VMI system with consignment-based revenue-sharing contracts, is an advanced information system, including electronic data interchange

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and Internet-based exchange, which can decrease data transfer time and number of entry mistakes (Lee et al., 1999; Dejonckheere et al., 2004). This work fills the gap between production and marketing decision-making by developing model-driven optimization-based policies in a vertically decentralized single-manufacturer and single-retailer dynamic channel over a multi-period planning horizon. Moreover, this work develops policies for a VMI system in which consignment with a revenue-sharing contract is applied to solve the problem of optimally dynamic decisions in business-to-business (B2B) traditional markets (TMs) and electronic markets (EMs).

Electronic markets are an increasingly important research topic in the IT domain (Kaplan and Sawhney, 2000). Via advances in technology, Internet-based EMs, which typically have low transaction cost and are easily searched by buyers and sellers, have changed the way in which trade is conducted in a channel (Gunasekaran et al., 2002; Hausen et al., 2006). Notably, EMs reduce procurement costs by a few percent to 40% depending on the industry, on average, approximately 15% (Simchi-Levi et al., 2008). Wang and Benaroch (2004) demonstrated that supplier and buyer decisions about whether to join a B2B EM depend on the revenue structure of the EM owner, and that the optimal replenishment quantity decision with a full return policy under a single-period newsvendor supply chain in EMs can increase the channel efficiency. An EM system is an inter-organizational information system that exists away from the physical location of a TM, serves as an intermediary between buyers and sellers in a vertical market, and allows buyers and sellers to exchange information about prices and goods (Bakos, 1991). The latest ITs enhance inter-organizational interactions between production and marketing, such as those in customer relationship management, enterprise resource planning (ERP), decision support systems (DSSs), SCM, and EMs. In recent years, SCM with the growth of ERP has become an important focus of decision support applications, and the difficulty in obtaining the data required to model supply chains has decreased due to ERP (Power and Sharda, 2007). Model-driven optimization-based DSSs are typically applied to such SCM stages as transportation, manufacturing, capacity, demand, replenishment, and pricing. Vigus et al. (2001) reported that the Kellogg Company saved millions of dollars by using model-driven optimization-based systems. Smith et al. (2003) developed a model-driven DSS that maximizes profit for a retail supply chain with multiple vendors. However, information system benefits cannot be fully realized without a finely tuned alignment and reconciliation between system configurations, organizational imperatives, and core business processes (Al-Mashari et al., 2003). Further, the fundamental basis of planning and scheduling in an information system is based on fixed and static settings (Petty et al., 2000; Hsiang, 2001). As a result, the system generates suboptimal solutions to the pricing and lot-size/scheduling problem. Supply chains are dynamic systems that evolve over time; that is, customer demand changes over time, as do supply chain relationships (Simchi-Levi et al., 2008). Numerous studies have implicitly assumed that enterprises cannot control demand, when in fact this is untrue. In a competitive business environment, enterprises have relied heavily on the dynamic pricing scheme to improve their net profits. Owing to its effectiveness in demand-side control over on-hand stock that generates considerable profits, dynamic pricing schemes are increasingly prevalent in retailing and e-commerce merchandising (Boyd and Bilegan, 2003). Furthermore, deterioration affects numerous inventory items, such as fashion goods and high-tech products, which are subject to depletion by phenomena other than demand—such as shrinkage and obsolescence. Deteriorating inventory problems have attracted recently significant research attention.

The representative research on dynamic pricing and lot-sizing planning models with deteriorating items includes Cohen (1977), Rajan et al. (1992), Abad (1996, 2001, 2003), Wee (1997), Wee and Law (2001), and Papachristos and Skouri (2003). Cohen (1977)'s model deals with simultaneously setting price and production levels for an exponentially decaying product under standard EOQ cost assumptions. The model proposed by Rajan et al. (1992) jointly determines the optimal replenishment cycle and price for inventory that is subject to continuous decay and value drop over the inventory cycle, where the price is a function of time. Abad (1996) extended the model of Rajan et al. (1992) by allowing shortages that can be partially backlogged at the end of the cycle. The subsequent models (Wee, 1997; Wee and Law, 2001; Abad, 2001, 2003; Papachristos and Skouri, 2003) are variants of Rajan et al. (1992) and Abad (1996) that deal with the problem under a single period setting and considering additional factors such as quantity discount, partially backlogged, or economic production quantity. Instead, this work develops an optimization-based scheme as a dynamic integrated production and marketing decision-making model using a calculus-based formulation combined with dynamic programming (DP) to solve the joint retail price and replenishment quantity/scheduling decision problem for deteriorating goods within a vertically decentralized single-manufacturer and single-retailer supply chain in both EMs and TMs.

This work differs from the aforementioned work, in several aspects. First, this work considers the dynamic joint decision problem over a finite planning horizon, which represents the product lifecycle and consists of multiple inventory cycles. In the aforementioned work, the pricing and replenishment policy are jointly determined within an inventory cycle. Second, this study examines the dynamic performance of decentralized channels under a retailer-managed inventory (RMI) system with a price-only (PO) contract and a VMI system with a consignment contract in EMs and TMs, respectively; the channel sells a perishable product with a multivariate demand function of price and time. A third difference between this work and past research is that the proposed scheme may adjust the selling price upward or downward periodically over the planning horizon that makes the pricing policy more responsive to the fluctuations of supply or demand over product lifecycle. The models proposed by Rajan et al. (1992) and Abad (1996) can only adjust the price downward, due to the value drop effect, within the inventory cycle. One of their major drawbacks is the inability to react to the market trend in demand over product lifecycle. In other words, they focused on short-term control over a single inventory cycle; this work dealt with mid-term to long-term control over the product lifecycle. Other models proposed by Cohen (1977), Wee (1997), Wee and Law (2001), Abad (2001, 2003), and Papachristos and Skouri (2003) assume that the endogenous price is fixed over the inventory cycle. Additionally, this research proposes the dynamic joint channel decision problem taking time-value of money into account, i.e., the net present value (NPV) approach. The reason of adopting NPV is due to its practical use in business planning and financial decision making (Sun and Queyranne, 2002).

The remainder of this study is organized as follows. Section 2 describes the problem context. Sections 3 and 4 develop the mathematical models and solution procedures for decentralized channels under RMI with a PO contract and VMI with a consignment contract in B2B TMs and EMs, respectively. Section 5 compares solutions generated by the four proposed policies and applies sensitivity analysis to key parameters. Finally, Section 6 presents concluding remarks and suggestions for future research.

## 2. The problem context

This section characterizes the problem and contexts, including assumptions and the necessary notations. An RMI system with a PO contract is typical in vertically decentralized channel coordination, namely, the traditional trading form in which the retailer is