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Managing inventories in a two-echelon dual-channel supply chain

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Abstract

We present a two-echelon dual-channel inventory model in which stocks are kept in both a manufacturer warehouse (upper echelon) and a retail store (lower echelon), and the product is available in two supply channels: a traditional retail store and an Internet-enabled direct channel. The system receives stochastic demand from two customer segments: those who prefer the traditional retail store and those who prefer the Internet-based direct channel. The demand of retail customers is met with the on-hand inventory from the bottom echelon while the demand in the Internet-enabled channel is fulfilled through direct delivery with the on-hand inventory from the upper echelon. When a stockout occurs in either channel, customers will search and shift to the other channel with a known probability. A one-for-one inventory control policy is applied. In order to develop operational measures of supply chain flexibility, we define a cost structure which captures two different operational cost factors: inventory holding costs and lost sales costs. We discuss several insights that are evident from the parametric analysis of the model. We also examine the performance of two other possible channel distribution strategies: retail-only and direct-only strategies. Computational outcomes indicate that the dual-channel strategy outperforms the other two channel strategies in most cases, and the cost reductions realized by the flexibility of the dual-channel system may be significant under some circumstances.

Keywords: Inventory; Supply chain management; Channels of distribution; E-commerce; Direct marketing

1. Introduction

Consider a two-echelon inventory system that consists of a manufacturer with a warehouse at the top echelon and a retail store at the bottom echelon. The manufacturer uses both a traditional retail store and an Internet-enabled channel to distribute its products. Demand from customers at the retail store is met with the on-hand inventory from the bottom echelon while orders placed through the Internet-enabled channel are satisfied directly with the on-hand inventory from the top echelon. Such a system is called a two-echelon dual-channel distribution system, or, more

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generally, a multi-echelon multi-channel distribution system.

The advent of the Internet has made it easier for companies who traditionally distribute their products through retail stores to engage in online direct sales. It has facilitated the adoption of multi-channel distributions. Moriarty and Moran (1990) pointed out that dual or multiple channels would become the dominant design for computer industry in the 1990s. In fact, the movement to multiple channels of distribution has also occurred in other industries. According to a recent survey, about 42% of top suppliers in a variety of industries, such as electronics, appliances, sporting goods, and apparel, have begun to sell directly to consumers over the Internet (Tedeschi, 2000). Evidently, as indicated by Keskinocak and Tayur (2001), companies are increasingly using new Internet-enabled sales channels along side the traditional retail channels to achieve supply chain flexibility.

Although the Internet-enabled channel is the motivation of this paper, the adoption of dual-channel distribution is not a novel phenomenon in the e-business era. Dual-channel distribution may take many forms, one of which is when a manufacturer both sells through intermediaries and directly to consumers (Preston and Schramm, 1965). The literature on distribution channels has pointed out important economical reasons for serving different customer segments with different channels (e.g., Moriarty and Moran, 1990; Rangan et al., 1992; Anderson et al., 1997). Because customers are heterogeneous in terms of their channel preference (Kacen et al., 2002), multiple channels may reach potential buyer segments that could not be reached by a single channel and may thus help to increase the market coverage. Also, dual channels may help companies to increase customers' awareness and loyalty of their products.

Despite its advantages, the adoption of dual-channel distribution introduces new management concerns. From a logistics perspective, combining the existing retail distribution channel with a new Internet-based direct distribution channel may cause havoc on the product demand structures, and thus may require companies to redesign the optimal inventory allocations in the two-echelon distribution environment. The fundamental task in connection with the two-echelon inventory problem is to find the balance between the stock levels at the top and the bottom echelons. How do companies set stock levels to achieve better channel performance when a new Internet-based direct distribution is introduced alongside the existing retail channel? In this paper, we incorporate the Internet-enabled direct channel into a traditional two-echelon inventory system and construct a model to determine the optimal inventory control levels for each echelon.

The analysis of multi-echelon inventory systems that pervades the business world has a long history. Clark and Scarf (1960) introduced the concept of echelon stock. Inventory control in multi-echelon systems is known to be a challenging research area. Because of the complexity and intractability of the multi-echelon problem, Hadley and Whitin (1963) recommend the adoption of single location, single echelon models for the inventory systems. Sherbrooke (1968) constructed the METRIC model, which identifies the stock levels that minimize the expected number of backorders at the lower echelon subject to a budget constraint. This model is the first multi-echelon inventory model for managing the inventory of service parts. Thereafter, a large set of models that generally seek to identify optimal lot sizes and safety stocks in a multi-echelon framework were produced by many researchers (e.g., Deuermeyer and Schwarz, 1981; Moinzadeh and Lee, 1986; Svoronos and Zipkin, 1988; Axsäter, 1990, 1993; Nahmias and Smith, 1994; Aggarwal and Moinzadeh, 1994; Grahovac and Chakravarty, 2001). In addition to analytical models, simulation models have also been developed to capture the complex interactions of the multi-echelon inventory problems (e.g., Clark et al., 1983; Pyke, 1990; Dada, 1992; Alfredsson and Verrijdt, 1999).

The study of multi-channel supply chains in the direct versus retail environment has emerged only recently. The focus of this stream of literature is on channel competition and coordination issues in the setting where the upstream echelon is at once a supplier to and a competitor of the downstream echelon (e.g., Rhee and Park, 1999; Tsay and Agrawal, 2003; Chiang et al., 2003). These papers