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Inventory control in a two-echelon dual-channel supply chain with setup of production and delivery

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ABSTRACT

This paper considers a two-echelon dual-channel supply chain model with setup of production and delivery and develops a new inventory control policy for the supply chain. Previously, a two-echelon supply chain model without setup of production and delivery is considered and a one-for-one inventory control policy is applied to the supply chain. In the inventory control policy, production is stopped when the warehouse inventory reaches the upper limit and is started again immediately after the inventory drops below the limit. Moreover, delivery to the retailer is stopped when the store inventory reaches the upper limit and is started again immediately after the inventory drops below the limit. The total cost that consists of inventory holding costs and lost sales cost is considered, and setup costs are not considered in the total cost. Once setup costs are introduced, the one-for-one inventory control policy is no longer appropriate. Then, this paper develops a new control policy for the two-echelon dual-channel supply chain with setup of production and delivery. As performance measure, the total cost that consists of inventory holding costs, lost sales cost, and production and delivery setup costs is considered, and the total cost calculated on the basis of Markov analysis demonstrates the effectiveness of the proposed control policy.

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1. Introduction

This paper considers a two-echelon dual-channel supply chain model with setup of production and delivery and develops a new inventory control policy for the supply chain.

Recently, in the SCM field, new channels for supply chains have attracted much interest (see for example, Agatz et al., 2008; Chen et al., 2008; Huang and Swaminathan, 2009; Kumar and Ruan, 2006; Tsay and Agrawal, 2004; Yao and Liu, 2003). Retailers comprise a traditional channel in supply chains. However, since the internet made on-line shopping easy, it has become an important retail channel as well. Dual-channel supply chains are thus becoming more common. In dual-channel supply chains, customers select the channel through which to buy goods, so dual channels mean more shopping choices and potential cost savings to customers. To traditional retailers and manufacturers, however, the implications for their strategic and operational decisions are not clear. Traditional supply chain models are not sufficient for developing insights into the equilibrium performance of such supply chains. Therefore, several models for addressing these issues have been developed.

For example, Chiang et al. (2003) considered the design of dual channels in SCM. Lee et al. (2000) and Li (2002) estimated the value of information sharing in two-level supply chains and in a supply chain with horizontal competition. Yue and Liu (2006) considered demand forecast sharing in dual-channel SCM. Although they considered dual-channel SCM, they did not develop a dual-channel supply chain model or inventory control methods.

Dumrongsiri et al. (2008) develop a dual-channel supply chain model in which a manufacturer sells the same product to a retailer as well as directly to consumers, and consumers choose which channel to use to buy the product. Their exact analysis led to conditions for dual-channel equilibrium, and further analysis revealed the effects of demand variability on the supply chain structure. They showed that adding a direct channel increases the total profit if adding such a channel is feasible. However, in considering the profit, they did not consider control of inventory in each channel.

Inventory control problems with multiple channels have been considered as a two-echelon inventory system with a central warehouse and a number of retailers. There have been many studies of the two-echelon inventory system (see for example, Schwarz, 1973; Schwarz et al., 1985; Anily and Federgruen, 1990, and recently Levi et al., 2008). The difference between the original two-echelon inventory system and the more recent dual-saleschannel system is direct upstream demand. Axsäter et al. (2001)

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considered the relationship between the original and recent systems and proposed a technique for handling the direct upstream demand in the original two-echelon inventory system. Their technique obtains an optimal reorder point for a prespecified order size.

Chiang and Monahan (2005) presented a two-echelon dualchannel supply chain model in which stocks are kept at both a manufacturer warehouse and a retail store and applied a one-forone replenishment policy (Svoronos and Zipkin, 1991) to the supply chain. Under the control policy, production is stopped when the inventory at the warehouse reaches the upper limit and is started again immediately after the inventory drops below the limit. Moreover, delivery to the store is stopped when the inventory at the retailer reaches the upper limit and is started again immediately after the inventory drops below the limit. They defined the total cost as the sum of inventory holding costs and lost sales cost, and they have not considered setup costs. Once setup costs are introduced, their control policy is no longer appropriate.

In this paper, we consider a two-echelon dual-channel supply chain model with setup of production and delivery and develop a new inventory control policy for the supply chain. In the supply chain, the product is available through two channels, and customer demand is stochastic. The demand by retail store customers is met with the inventory at the retailer while the demand by internet-customers is met through direct delivery with the inventory at the manufacturer. When a stockout occurs in either channel, customers shift to the other channel with a known probability. The total cost consisting inventory holding costs, lost sales cost, and production and delivery setup costs is considered. Calculation of the total cost using Markov analysis and numerical calculations demonstrated the effectiveness of the proposed control policy.

The rest of this paper is organized as follows. In Section 2, a two-echelon dual-channel supply chain model is described defining the model assumptions and the inventory control policy. A Markov chain model and flow balance equations for the previous and proposed policies are described in Section 3. In addition, the performance measures for the policies are formulated. In Section 4, the numerically calculated performance of each policy under various conditions is presented, and the effects of rates and cost parameters are described. Finally, in Section 5, the key points are summarized and future research work is mentioned.

2. Two-echelon dual-channel supply chain model

The two-echelon dual-supply chain model considered here is shown in Fig. 1. The assumptions and control policies are described in this section.

2.1. Model assumptions

- 1. The product is available to customers through two channels, a retailer channel and an internet-based direct channel.
- The inventory at the retailer is used to satisfy the demand arriving through the retailer channel, and the inventory at the warehouse is used to satisfy the demand arriving through the direct channel and to replenish the retailer inventory.
- 3. The product price is the same for both channels.
- 4. The system receives stochastic demand from two customer segments: those who prefer the retailer channel and those who prefer the direct channel.
- Each customer segment has an independent demand arrival rate.

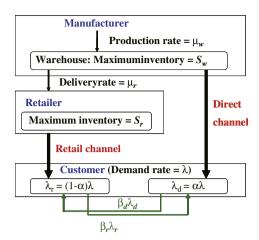


Fig. 1. Two-echelon dual-channel supply chain model.

- 6. Demand through the retailer channel arrives in accordance with a Poisson process at constant rate λ_r and is met with the inventory at the retailer.
- 7. Demand through the direct channel arrives at the manufacturer directly in accordance with a Poisson process at constant rate λ_d and is met through direct delivery with the inventory at the manufacturer. The inter-arrival time between successive demands follows an exponential distribution with mean $1/\lambda$.
- 8. The total demand arrival rate is λ (= $\lambda_r + \lambda_d$). The direct channel preference rate is α , so $\lambda_d = \alpha \lambda$, $\lambda_r = (1-\alpha)\lambda$.
- 9. Backorders are not allowed. When a stockout occurs at the retailer, some proportion, β_r , of the arriving customers switch to the direct channel. When a stockout occurs at the manufacturer, some proportion, β_d , of the arriving customers switch to the retailer. The demand of the other customers is lost. In addition, when a stockout occurs at both the retailer and manufacturer, all the arriving demand is lost. Thus, β_r can be called the retail-customer switch rate, and β_d can be called the direct-customer switch rate.
- The lead time from releasing an order to starting inventoryreplenishment to make up for the released order is neglected.
- 11. The inventories at the retailer and manufacturer are replenished from the warehouse and the manufacturer, respectively, in accordance with a Poisson process at constant rates μ_r and μ_w , respectively. That is, there is a two-echelon supply system. The replenishment times for the retailer and manufacturer follows an exponential distribution with means $1/\mu_r$ and $1/\mu_w$, respectively.

2.2. Inventory control policy

As shown above, this paper considers a two-echelon dualchannel supply chain model with setup of production and delivery and develops a new inventory control policy for the supply chain. As performance measure, the total cost that consists of inventory holding costs, lost sales cost, and production and delivery setup costs is considered. Then, policies are considered here for reducing the inventories at the warehouse and retailer, the lost sales, and the number of production and delivery setups in order to minimize the total cost.

The inventory at the warehouse is x, and the inventory at the retailer is y. The state (x,y) changes with demand arrival through the direct channel at rate λ_d , with demand arrival at the retailer at

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