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A (Q, R) inventory model with a drop-shipping option for e-business☆

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ABSTRACT

Drop shipping is used by online as well as traditional retailers as an order fulfillment strategy. A retailer simply forwards customers' orders to the manufacturer or a distributor who fills the orders directly to the customers and is paid a predetermined price by the retailer. For the retailer, advantages of drop shipping include lower holding, handling, and shortage costs. Disadvantages include increased per-unit cost, fragmented order delivery when a single customer order involves products from different manufacturers, longer delivery times, and increased order processing cost.

In this paper, we develop two (Q, R) inventory models that allow a retailer to use the drop-shipping option in case of a shortage during lead-time. In the first model, the units short are backordered whereas in the second model sales are lost. We provide closed-form results for exponential and uniform demand distributions. We perform numerical sensitivity analysis and illustrate the results with numerical examples.

1. Introduction

The ability to provide a good customer service level in e-business is critical to the success of e-retailers. According to Saliba [1], "fulfillment problems have been an ongoing nightmare for many e-retailers." An Accenture study [1] found that "during the crucial holiday season, as many as 67% of online deliveries were not received as ordered, and 12% were not received in time for the Christmas holiday." PricewaterhouseCoopers, found similar results with shoppers identifying order fulfillment as their most persistent frustration for online shopping [1].

High-speed communication and tight connectivity brought about by the Internet enable supply chains to be much more flexible and enhance their ability to improve customer service [2]. The ability to use drop shipping to respond to customers' demand is such an improvement provided by the Internet. With drop shipping, an e-retailer simply forwards customer orders to manufacturers who fulfill those orders directly to the customers for a predetermined price to be paid by the e-retailer [3–5]. This paper is motivated by an actual case of a manufacturer who offers its large retail customers to drop ship products to their customers when the retailers have a stockout and have an order outstanding with the manufacturer. The manufacturer currently charges the retailers the same per-unit cost for drop shipping as for regular replenishment orders. The drop-shipping option is currently offered only to large retail customers. The manufacturer is contemplating offering drop shipping to all its retail customers at a premium over the per-unit cost of the regular replenishment orders. The problem facing the retailers is to develop an inventory policy that takes into account the drop-shipping option.

To investigate the effect of drop shipping on non-perishable inventory systems, we consider its use in a continuous-review order quantity reorder-point (Q, R) inventory model [6]. Under the (Q, R) policy, a retailer orders Q units when inventory position

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falls to R units. The Q units arrive after a fixed deterministic lead-time has elapsed. Shortages during lead-time are treated as lost sales, backorders to be satisfied when the order arrives, or a combination of both [6]. In this paper, we formulate two (Q, R) inventory models in which retailers use a drop-shipping option when a shortage occurs during lead-time. In the first model, the units short are backordered whereas in the second model sales are lost. We derive closed-form expressions for the optimal solutions under exponential and uniform demand distributions. We perform numerical sensitivity analysis and solve some examples.

Our findings indicate that the availability of the drop-shipping option will decrease both the optimal reorder point and the optimal order quantity. This decrease is largest when the ratio of the per-unit drop-shipping penalty cost relative to the backorder cost is small, the per-unit holding cost is large, and the lead-time is long. In such a case, the optimal reorder point may become zero. Furthermore, the analysis indicates that the drop-shipping option effect on the optimal reorder point and the optimal order quantity depends on whether the fraction of demand which cannot be drop shipped during stockouts is backordered or lost. For the case of lost demand, if unit profit margin is high then the availability of drop shipping will have only a small effect on inventory policy, especially when the fraction of demand which can be drop shipped is small.

2. Literature review

Drop shipping has significant advantages for the retailer over holding inventory. These advantages include savings in the holding cost, significant reductions in shipping and processing costs [7] and increased customer satisfaction as a result of better service. According to Huppertz [8], "direct store delivery (DSD) or drop shipping is how some trading partners avoid the cost of handling smaller orders in a retailer's or a distributor's distribution center. By letting the supplier ship the order directly to the store or end customer, a whole step is removed from the supply chain and the retailers (or buyers) achieve their objective of pushing inventory upstream to suppliers." Drop shipping also provides trading partners advantages in dealing with very short shelf life items that "cannot afford to spend time flowing through extra distribution steps or sitting in a distribution center for any length of time" [8]. Eliminating a handling step can reduce product damages for such items. Manufacturers providing drop-shipping services can also benefit from increased sales and a reduction in advertising costs. Surveys indicate that about 30% of pure US Internet retailers rely heavily on drop shipments for order fulfillment [9].

In spite of its advantages, many e-retailers have found that drop shipping cannot be used as the only option for satisfying demand [3,10,11]. A major drawback of drop shipping is that a single customer order may include products from different manufacturers and therefore will be fragmented. This fragmentation causes an increase in shipping costs and is annoying to many customers. Additionally, drop shipping may have longer delivery time, which is a critical measure of customer service. Suppliers who are not set up to "handle small pick-pack types of orders" or "cannot do so as efficiently as the retailer" cannot be used to drop ship [8].

Many e-retailers now use a mix of drop shipping and in-house inventory to satisfy demand in case of a shortage. The mix strategy enables e-retailers to capture some of the drop- shipping advantages while avoiding its drawbacks. Khouja [12] incorporated a drop-shipping option into the single-period model framework and showed that it can lead to a significant increase in expected profit. A limitation of the single-period model is that it deals with perishable products and is inappropriate for many products with long shelf life. The drop-shipping option is more valuable in the single-period model than it is in the multi-period models because drop shipping allows the retailer to partially shift the obsolescence or perishability cost, which is not a consideration in the multi-period framework, to the supplier.

Netessine and Rudi [13] analyzed drop shipping in a single-wholesaler and a single-retailer supply chain. The analysis was conducted under different power structures and included marketing and operational costs. The retailer carries out the marketing and advertising activities and the wholesalers handles the fulfillment business. Ayanso et al. [9] developed a simulation model for an e-retailer operating in a business to consumer (B2C) environment and selling made-to-stock items. The model is developed for stochastic demand and lead-time. The e-retailer utilizes drop shipping for filling customer orders. The simulation identifies the stock level below which low margin orders are drop shipped directly from the supplier. Hovelaque et al. [14] assessed three different organizational forms that can be used when a store-based sales network coexists with a web site order network. The three organizational forms are "store-picking," "dedicated warehouse-picking" and "drop shipping." The authors use a newsvendor type order policy model to compare the three different models and to analyze the impact of some parameters on inventory policies in the supply chain.

Related models are those dealing with inventory policies under substitutability [15,16], centralized or decentralized supply chains where the manufacturer sells directly to consumers [17,18], and competing brick-and-mortar and e-retailers [19]. Bassok et al. [15] developed a multi-product single-period model with substitution. The authors assumed N products and N demand classes with full downward substitution and assumed that the substitution cost is proportional to the quantity substituted. The formulation results in a two-stage decision model. In stage I, the NV decides on the optimal order quantities. In stage II, after observing demand, the NV decides how to allocate the optimal order quantities among the N demand classes. Parlar and Goyal [16] developed a two-product single-period model in which each product can substitute for the other in case of a shortage. The authors assumed that salvage value and the lost sales penalties are zero and that substitution occurs according to fixed probabilities. Other models that dealt with substitutability can be found in the literature [20,21]. Yao et al. [18] considered a two-stage supply chain with a retailer and a manufacturer who has a direct channel to consumers. The authors analyzed inventory