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Production and pricing policies in dual sourcing supply chains

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ABSTRACT

We analyze optimal production and pricing strategies in the single period (newsvendor) dual sourcing problem that entails local and offshore suppliers. The local supplier is used reactively as an emergency source following the realization of random demand. A multiplicative demand model is employed. We show that dual sourcing flexibility may decrease optimal price when emergency supply cost is sufficiently low. We also find that optimizing price for a given stocking factor yields a price which is always higher than the price in the case where both price and stocking factor are selected to be jointly optimal.

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1. Introduction

The tradeoffs associated with the single period (newsvendor) inventory problem appear in the modeling of a wide variety of phenomena. The applications range from scheduling operating rooms in hospitals to production of high-tech consumer electronics goods with short life cycles. In the context of inventory management, the key decision is the amount of stock to hold to satisfy uncertain future demand for a product.

An extension of the classic newsvendor problem considers the possibility of backordering excess demand when the realized demand exceeds the inventory on hand (e.g., Karakaya and Bakal, 2013; Pando et al., 2014). The backordered demand is met by emergency production/shipment. For example, Lee and Lodree (2010) discuss the scenario of textbook ordering by a bookstore. The bookstore places an emergency order for outstanding shortages upon observing demand. Because the emergency order placed by the newsvendor needs to be fulfilled in a short time, the unit procurement cost associated with the emergency order will typically be higher than that associated with the regular pre-season order for which the supplier is allowed a longer lead time. Besides the increased production cost, the cost of transporting the product from the supplier to the buyer is likely to be higher for the emergency shipment as a faster transportation mode may be required for expedited delivery. The production before observing the demand and the production after observing the demand may be referred to as make-to-stock and make-to-order production approaches, respectively. Both production alternatives have their own associated risks. Make-to-stock mode of operation entails cost of leftover inventory whereas make-to-order mode of operation entails cost of idle capacity (Cachon and Terwiesch, 2009).

It may be thought that the newsvendor problem with backordered demand represents a situation where two supply modes are used jointly by a manufacturer. The internal manufacturing that can be completed in a relatively shorter time is supported by outsourcing that requires a longer lead time. The athletic wear or fashion apparel companies using global

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sourcing can combine offshore make-to-stock production with onshore quick response manufacturing to maximize their profit (Warburton and Stratton, 2005). The emerging countries such as China offers the advantage of low production cost but the long distance between them and the retailers located in developed countries necessitates that the production order should be placed at a time significantly earlier than the selling season, as usually a slow delivery mode such as ocean cargo is used to reduce the transportation cost (Choi, 2013). The need for placing the order before observing the random demand implies that the firm faces the risk of losing money on items which are not sold during the selling season. The local suppliers, while involving a higher production cost, can operate under a shorter lead time because of their physical closeness to the retailers and the possibility of shipping the products by trucks and trains on land. The dual sourcing strategy tries to combine the low-cost advantage of offshore supply with the quick response capability of local supply. Compared to offshore supply, local supply offers the advantage of eliminating the risk of unsold inventory because the production amount is determined after demand realization; the local production quantity can be set exactly equal to the shortage observed. Thus the more weight the local source is given in the production plan, the lower the expected cost of leftover inventory for the firm. The optimal allocation of production between offshore and local suppliers can be determined by solving a newsvendor model that allows backordered demand. Rosic and Jammernegg (2013) study environment-related extensions of the dual sourcing newsvendor model in which either carbon emissions arising due to transportation are penalized by an emission tax or the firm is given a limited number of tradable carbon emission allowances.

Warburton and Stratton (2005) also discuss that the idea of using responsive production capacity can be applied to the problem of finding the optimal allocation of manufacturing between offshore yarn dyeing and onshore garment dyeing. In this problem, coloring of a portion of garments can be postponed to a stage after the demand observation, which reduces the risk of having to markdown inventory at the end of the season.

Another real-world example for the dual order newsvendor problem is the practice of drop shipping by Internet retailers. These retailers try to meet demand first by using their own stock which is procured at a relatively low wholesale price. In case their inventory is not sufficient to meet all demand, the excess demand is met by a wholesaler that directly ships to the customers (Bailey and Rabinovich, 2005; Netessine and Rudi, 2006). A similar practice can be observed in the operations of brick-and-mortar retailers such as Gap Inc., Best Buy, and Office Depot. The fast-ship option offered by these retailers ensures that when customers cannot find an item in store, the item is shipped directly from the supplier to the customer free of delivery charge (Chen et al., 2013).

The mathematical model we use to study the dual sourcing problem can also be useful in the context of transportation planning when different transportation modes are available in a logistics network. The regular transportation services require long lead times whereas more costly expedited transportation services can facilitate delivery of products in a very short time which reduces the stockout risk (Kiesmuller et al., 2005; Li, 2013). Hence the modeling approach for the dual supplier problem can be applied to exploring the issue of choosing the optimal mix of transportation services in designing the logistics networks.

In some studies of the newsvendor problem, the selling price for the product is also treated as a controllable variable, resulting in an optimization problem with two decision variables-order quantity and price. Early explorations of this two-variable problem in the literature include Whitin (1955) and Mills (1959). While solution of the newsvendor problem when demand is independent of price is straightforward, the solution of the problem when demand depends on price requires a more careful analysis as the unimodality of the profit function is not ensured under all circumstances.

We contribute to the current literature on quick response manufacturing with offshore and onshore suppliers by considering endogenous selling price, and describing general properties of the jointly optimal production and pricing policy. In the context of dual sourcing with offshore and onshore supply sources, the traditional newsvendor problem with lost sales corresponds to the scenario where only the offshore supplier is used by the buyer. The maximum expected profit associated with dual sourcing strategy is always greater than or equal to the maximum expected profit associated with single sourcing strategy, as single sourcing is one of the alternatives available to the buyer in the more general dual sourcing problem. But it is not obvious how optimal stocking and pricing decisions vary between single sourcing and dual sourcing strategies. To our knowledge, there is no previous work in the literature comparing the optimal policies in the single sourcing and dual sourcing problems. We address the following research questions that have not been fully explored before. Does the introduction of local (emergency) supply always lead to a higher selling price? How does demand uncertainty affect the optimal policy? What is the effect of local supply cost on the optimal stocking and pricing decisions? How does optimal price change if the stocking and pricing decisions are not coordinated?

The newsvendor problem with price-dependent demand has attracted significant attention in recent years, and there are many studies related in varying degrees to this problem. Some representative examples are Yao et al. (2006), Song et al. (2008), Chen et al. (2009, 2010), Xu et al. (2010), Leng and Parlar (2010), Chiu et al. (2011), Chen and Bell (2011), Shi et al. (2011), Xu and Bisi (2012), Arcelus et al. (2012), Chen and Chang (2012), Jammernegg and Kischka (2013), and Wang et al. (2013). More information about main characteristics of the price-setting newsvendor problem can be found in Petruzzi and Dada (1999), Qin et al. (2011), and Chen and Simchi-Levi (2012).

With the exception of a few papers (e.g., Agrawal and Seshadri, 2000) the previous work on the newsvendor problem with backordered demand has generally considered that demand is independent of the selling price. Agrawal and Seshadri (2000) mainly focus on the effect of risk aversion on the optimal price and inventory choice; they characterize the optimal policy under both the additive and multiplicative demand assumptions. They also present results for the special case of risk neutral

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