A two-stage capacity reservation supply contract with risky supplier and forecast updating

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ABSTRACT

We propose a single product two-stage supply contract between a retailer and a main supplier. The retailer buys a number of supply options for a non-refundable price from the main supplier at the beginning of the first decision stage (first period), which can be seen as capacity reservation. At the beginning of the second decision stage (second period), these options can be exercised for a given unit cost and transformed, by the retailer, fully or partially, into orders that are delivered by the supplier immediately. Moreover, the retailer faces a stochastic demand, which is concentrated in the second period and is modeled jointly with a correlated exogenous information using a joint probability distribution. In addition, a second supply opportunity from a risky supplier whose availability is random and modeled using a Bernoulli distribution may be available. At the beginning of the second decision stage, the stochastic exogenous information is revealed and the information about the availability or unavailability of the risky supplier becomes known. Therefore, the demand forecast is updated conditionally to the value of the exogenous information. Thus, if the risky supplier is available, another quantity may be ordered from this supplier by the retailer for a given unit cost and delivered immediately. The end-customer demand occurs during the second period and every satisfied demand is charged a given unit price by the retailer. At the end of the selling season, any remaining units are salvaged by the retailer at a salvage value.

We model this problem using a dynamic programming approach and we exhibit some characteristics of the structure of the optimal inventory control policy for the retailer. More specifically, we provide the structure of the second decision stage optimal policy and some analytical insights concerning the first stage optimal policy. Furthermore, through a numerical study, we analyze the effect of some of the model parameters on the optimal policy such as the information quality, the probability of the availability of the risky supply option, and the difference between the costs of the two supply options.

1. Introduction

Newsvendor-type products are seasonal products with their end-customer demand being concentrated in a short selling season. These products are usually perishable, which lead to salvage any remaining items after the end of the selling season at a salvage value that is less than the product original price. Many of these products are manufactured by an organization, the supplier, and sold to end-customers by another organization, the retailer, in a decentralized decision-making context. Moreover, decentralization has become a fact in many supply chains for different reasons. An example of decentralization is the outsourcing of the production activities to independent production units which automatically shifts the decision making authority (Tsay, 1999). In the current global economic context, another example of decentralization happens when different production sites within the same organization report to different functional entities, sometimes for incentive considerations. On the other hand, the manufacturing and logistics lead-times force retailers to take replenishment decisions before the beginning of the selling season, and therefore, before having an accurate estimation of the demand, which necessitates the use of forecasts. The high forecast inaccuracy or the uncertain nature of demand makes it better to use probability distributions to model the future end-customer demand. In inventory management, the most suitable model to determine the stocking levels for such Newsvendor-type products is the well known Newsvendor model (Khouja, 1999; Cheaitou et al., 2011). In this single period-model, the retailer orders a quantity at the beginning of the selling season.
season at a certain unit cost. The ordered quantity is delivered immediately and used by the retailer to satisfy an uncertain end-customer demand. During the selling season, any satisfied demand is charged a unit price and any unsatisfied demand is lost and a corresponding cost is incurred. At the end of the selling season, any remaining units are salvaged at a salvage value. Many extensions have been proposed in the literature to improve the Newsvendor model (Khouja, 1999). Some of these extensions model the problem using a two-period framework which allows the decision maker to react to any change in the demand during the first period (Cheaitou et al., 2009). Other extensions include the use of some information updating mechanisms allowing to improve the quality of the demand forecasts using either endogenous or exogenous information. Endogenous information may represent information about the actual demand of the same product in previous selling periods. Exogenous information may be collected, for instance, by sales representatives from the distribution of vouchers or quotations, or in e-businessness from the number of visits to a commercial website. For instance, the number of visits to a specific subpage, the “wish lists” completed by the webpage visitors about products of interest, or the incomplete shopping carts could indicate the interest of the buyers by a specific product (Cheaitou et al., 2014).

Another Newsvendor-type inventory management framework that allows a better coordination between the supplier and the retailer is supply contract. A supplier contract is an agreement between two parties in the supply chain, usually a supplier and a distributor or a retailer, in order to organize and optimize the production decisions of the supplier and the replenishment decisions of the distributor or retailer. Different types of supply contracts exist including the quantity-flexibility contracts, the backup contracts, the buyback contracts, and the option-future contracts (Cheaitou et al., 2010). The difference between these contracts lies mainly in the structure of the decision making process. Another differentiation aspect is the degree of coordination that these contracts may entail result in between the two contracting parties of the supply chain. A specific category of supply contracts that is the most relevant to the present work is the capacity reservation supply contract (Serel et al., 2001; Wang and Tsao, 2006; Xu, 2006; Jin and Wu, 2007; Serel, 2007). In this type of contracts, the supplier guarantees the delivery of any desired portion of a reserved capacity in exchange of a guaranteed payment by the buyer (Serel et al., 2001). To guarantee good availability levels of their Newsvendor-type products during the selling season, retailers can place their purchase orders with reliable suppliers long time before the start of the selling season (Serel, 2008) using capacity reservation contracts. In some other cases, existing constraints on supply capacity or on the production and transportation lead-times prompt retailers to make early commitments. This is what happens in the fashion industry for example (Serel, 2009).

Fisher and Raman (1996) state that, “typically, two years are required from the start of design and one year from the start of production until a garment is sold”. These authors show through their study about the inventory management system of a major fashion skitwear manufacturer, Sport Obermeyer, how these long lead-times affect the performance of the company and propose the use information updating processes and systems such as the Quick Response inventory control system (Fisher and Raman, 1996). However, placing an order at an early stage, and long time before the selling season, may make it difficult for the retailer to adjust this order when the selling season starts because of the pressure that may exist on the reliable supplier from the different retailers. Moreover, between the moment when the order is placed and the beginning of the selling season, the retailer may collect some information that can be useful to update the initial demand forecast. If the updated demand forecast indicates a rise in the demand, compared with the initial forecast, and to cope with the limited possibility of adjusting the supply of the reliable supplier during the selling season, a backup supplier can be used. A backup supplier is a secondary supplier that is used when a primary supplier is not available (Kamalahmadi and Parast, 2017). Such backup supply agreements exist in the fashion garments industry (Eppen and Iyer, 1997; Serel, 2008). Moreover, the split of orders between a reliable but expensive supplier and/or cheap but unreliable supplier is used as a lever to cope with supply risk and to minimize cost in supply chains (Kumar et al., 2018). In this context, we propose, in this work, a supply contract model that governs the relationship between a main supplier and a retailer in which two decision periods are considered. Moreover, the retailer faces a stochastic end-customer demand concentrated in the second period. This demand is modeled jointly with an exogenous information using a joint probability distribution. At the beginning of the first period, the retailer buys from the main supplier a number of supply options which can be seen as capacity reservation at a given non-refundable unit cost per supply option. Moreover, a backup supply option, considered as secondary, may be available at the beginning of the second period. The availability of this backup supplier is random which makes it a “risky supplier”. It is worth noting that the literature is rich with examples of cases in which relying on risky suppliers led to supply disruption, which makes considering this supply option and modeling its probability of availability relevant (Juttner, 2005; Serel, 2008, 2017; Li and Li, 2016). In addition, from the perspective of our model, two types supply risks exits: supply disruption, where there is a risk of a sudden complete stop of supply, i.e. when unexpected events occur and the supplier becomes totally unavailable; recurrent supply uncertainty, where the delivered volume differs from the ordered one (Hou et al., 2010). In this paper we consider the first category of supply risks where a risky supplier may be available or unavailable. The availability of risky suppliers has been modeled in the literature in different ways. We consider a Bernoulli process representation where there is a certain probability that the risky supplier is available and therefore the ordered quantity is fully delivered, and another probability that no deliveries occur at all (Gullu et al., 1999). At the beginning of the second period, the availability of the secondary supplier is either confirmed or not. Moreover, the value of the exogenous information is revealed and the demand probability distribution is updated accordingly. After the demand forecast is updated and the information about the availability/unavailability of the risky supplier is known, the retailer can then transform part or the totality of the supply options booked from the main supplier into orders for a given unit cost. Moreover, if the secondary supplier is available, the retailer can order another quantity from this supplier at a given unit price per ordered unit. Any quantity that is ordered from the main or the risky suppliers at the beginning of the second period is delivered immediately. At the end of the selling season, the remaining units are salvaged by the retailer. It is worth noting that, in addition to the apparel industry and other similar industries, another application of the proposed model can be the air transportation sector. In this industry, usually freight forwarders reserve a certain amount of capacity upon signing a contract with an air cargo carrier and execute the options partially or completely after the market demand is known (Tao et al., 2017). In this market, if the transportation demand to be satisfied by the freight forwarder on a given date turns out, after it is known, to be larger than the carrier scheduled capacity for that date, then the freight forwarder can use the spot market to fulfill the excess demand. However, for a particular date, the availability of air cargo capacity in the spot market cannot be guaranteed especially for the near future.

The remaining of this paper is structured as follows. The next section is dedicated to the literature review. In Section 3, the model assumptions are presented and the optimization problem is described. We present in Section 4 the solution approach of the second stage subproblem and the first stage subproblem as well as the optimal ordering policy. In Section 5 and Section 6, we study respectively two special cases: the perfect information setting and the worthless information setting. Section 7 is devoted to the numerical study in which we show the effect of some of the model parameters on the optimal policy. In the last section, we draw conclusions and we propose future research avenues.
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