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Supply chain coordination based on a buyback contract under fuzzy random variable demand

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Abstract

The demand of production is random in the supply chain. Furthermore, it is difficult to measure the demand in the real world. Hence, the interval is more likely to be used to present the demand. The interval can be viewed as a random variable. This paper introduces this random variable as the demand of production into the model of supply chain. We represent uncertain and fuzzy demand by a fuzzy random variable in a supply chain system based on a two-level buyback contract for a newsvendor model with a single cycle. For the sake of computational convenience, the crisp possibilistic mean which has been widely used in supply chain is employed to defuzzify the fuzzy random demand. In this paper, the expected profit is defuzzified using a crisp possibilistic mean value. The optimal order quantities in decentralized and centralized systems are analyzed and the conditions for supply chain coordination are obtained. A realistic example is presented to illustrate the effectiveness of supply chain coordination and the impact of mixed imprecise and uncertain demand on the retailer order quantities and the expected profits for all sides.

Keywords: Fuzzy random demand; Buyback contract; Supply chain; Fuzzy random variable; Fuzzy numbers; Newsvendor problem

1. Background and motivation

The aim of supply chain coordination is to improve supply chain performance by aligning the plans and the objectives of individual enterprises. Coordination usually focuses on inventory management and ordering decisions in distributed inter-company settings. The theoretical foundations of this coordination are based mainly on contract theory.

Supply chain coordination can be defined as identifying interdependent supply chain activities among supply chain members and devising mechanisms for managing these interdependences. It is a measure of the extent of

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implementation of aggregated coordination mechanisms that help to improve supply chain performance in the best interests of participating members [1].

The newsvendor model is not complex, but is sufficiently rich for studying important problems in supply chain coordination [2]. The model is also known as a single-cycle inventory model [15]. The classical newsvendor model is mainly used to solve the problem of an optimal product order for maximization of expected profit under random demand. It assumes that retailers will discount or clear any remaining inventory at the end of the product sales cycle. If the number of orders is less than the actual demand, retailers will lose profit opportunities. If the number of orders is greater than the actual demand, retailers will bear the risk of excess inventory and have to sell goods at a cheap rate. Because it is suitable for the marketing practices for products with a short life cycle, the newsvendor model is popular for academic and business studies [2].

For products with a short life cycle, demand forecasting is very important. Good prediction can effectively reduce inventory and short supply, increase market share and profits, and enhance competitiveness. This type of product is characterized by strong uncertainty, which means that the demand changes frequently. This leads to great challenges for decision-makers. In particular, for newly developed products it is difficult to obtain a statistical distribution of product demand because of the lack of relevant historical data. Therefore, before a product is released on the market it is difficult to obtain a good prediction of its demand. To solve this problem, fuzzy theory has been incorporated into the newsvendor model by many researchers and demand is defined as a fuzzy variable. This fuzziness corresponds well to estimation of the market demand. Therefore, such studies have attracted great interest.

Different studies have revealed different prediction estimates for the market demand [5]; some indicate that the demand is approximately D_1, some show that the demand is D_2, while others take it as a value which is between D_1 and D_2. Much effort has been devoted to overcoming this type of phenomenon. Kwakernaak is the first one to describe it by using fuzzy random variable [17]. This paper uses Kwakernaak's definition on fuzzy random variable.

There is a trend for shorter product life cycles, so the importance of the single-cycle model is increasing [10,15,38]. Researchers have proposed many extended supply chain models consisting of multiple subjects with different interests [15]. The greatest feature of these models is the *double marginalization effect*. When the market demand is strongly uncertain, the double marginalization effect is more obvious, which seriously affects the profits of all stakeholders [24]. The reason is that individual decision-makers always only consider their own interest rather than the overall interest. Because of dispersion in real supply chains, the double marginalization effect inevitably occurs in distributed systems with more than two members. Although this double marginalization effect is inevitable in the supply chain, coordination mechanisms can be used to mitigate or eliminate the problem whereby the decision that is optimal for independent individuals is inconsistent with the decision that is optimal for the system.

Among the incentive mechanisms for supply chains, a supply chain contract is the most effective [15]. A supply chain contract can reduce the opportunistic behavior of both partners by designing rational contracts and promoting close cooperation between enterprises to ensure effective delivery of completed orders for both sides, to assure product quality, to improve customer satisfaction, to reduce supply chain costs, and to improve the performance of both the whole supply chain and each member. It effectively means that the two sides are *risk-sharing, benefit-sharing*. According to their own circumstances, the two sides together determine the appropriate contract parameters to ensure that the overall profit for the supply chain under decentralized control equals that of a centralized system [15].

There are many types of supply chain contracts, such as buyback [7,32], quantity discount [21], quantity flexibility [19], revenue-sharing [3], sales rebate [2], and price discount contracts [2]. The best characteristic of a buyback contract is that it can flexibly eliminate the double marginalization effect for a system under random demand [15]. Extensive research on supply chain coordination for products with a short life cycle has led to increased attention on buyback contracts. From a management practice viewpoint, buyback is *risk-sharing* and plays a role in incentivizing orders. Therefore, a buyback contract can be of great value. In addition, buyback can not only help suppliers to protect their brands and promote the marketing of new products, but can also reduce the market risk borne by retailers. Agreement on a buyback contract means that suppliers begin to bear the costs for excess inventory led by market demand. Because of the symbiosis between risk (liability) and profit, the expected profit correspondingly increases.

An analysis of the literature reveals a lack of research on supply chain coordination under fuzzy random variable demand. Some studies do not consider the influence of short supply. Much previous research does not take into account how the negotiation ability of both sides affects the interests of all parties. In addition, existing research does not consider how changing demand affects the decisions of all stakeholders. It is necessary to study this type of