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Sequential price and quantity decisions under supply and demand risks

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ABSTRACT

Firms need to deal with not only risks from stochastic demand but also risks from supply side. The supply side risk may be due to parts/service outsourcing, third party logistics, or random yield in production processes. In this paper, we study how firms sequentially make price and quantity decisions under these two risks. The first question we try to answer is how these two risks affect the decisions and profits of the firm. We find that increased supply risk usually causes increased quantity/stocking decision, however, there exists a threshold level of supply risk above which the firm reduces quantity/stocking amount as supply risk increases. This observation may be used in a supply chain setting, where reduction of the supply risk can cause higher delivered quantity and improve supply chain performance. This observation also provides support and insights on prioritizing the risk reduction efforts from marketing and operations to achieve better coordination. At the same time, reduction of the risks help not only firms but also consumers as the optimal price decreases. To further improve decision making process under both uncertainties, we study the impact from information revelation and postponement of decisions. We compare results from different sequential decision making cases. As illustrated in the paper, firms gain competing advantage when decision postponement is available and this advantage becomes further significant as the risks increase. Our numerical examples also indicate that price postponement strategy is usually preferred but the relative profit difference between price postponement and quantity postponement become smaller as consumers become more sensitive to the price.

1. Introduction

Marketing and operations are two important functional departments of a company. The operations department usually makes either the replenishment decision or the production decision, which is generally named as the quantity decision in this paper. On the other hand, the prices of the products are usually jointly determined by different departments including marketing and accounting. As in the same firm, these two decisions are usually coordinated so that the market demand determined by the price decision can be satisfied by the supply affected by the quantity decision. In reality, making either decision could be complicated. For the price decision, since it affects the market demand, which is often assumed to be uncertain, the projection of anticipated revenue could be hard. At the same time, the quantity decision (either production or replenishment/procurement decision) affects the availability of the product; and there is always the risk that this availability may vary. This risk from the supply side is usually modeled as random yield risk, which may come from the supply process (i.e., outsourcing), the logistic process or the production process, or more generally, anything that may affect the availability of the products or services at the specified time and at the specified location. To name a few examples, a company will have supply risk due to long lead time, which usually causes higher lead time variability and supply uncertainty; or a company's supply may be affected by the reliability of its 3PL company; or a manufacturer may have the traditionally defined production yield randomness. These two risks from the market demand and the supply side interact and jointly affect the company's profitability. The first goal of this paper is to address the optimal price and quantity decisions under both the demand risk and the supply risk and study how the two risks jointly influence the firm. Furthermore, under this joint decision context and due to products or logistics characteristics, the firm may choose different sequences on the price and quantity decisions. The second goal of this paper is to study the sequential decision making under uncertainties. There are mainly two situations, quantity decision before price decision, and price decision before quantity decision. Examples for each situation can be found in reality. Specifically, for the sequential decision cases:

1. Pricing decision is made before the operational decision. This happens when the demand information is crucial for the supply chain due to its high volatility and the production/supply

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lead time is relatively short and reliable. The typical example of this type of products is the fashion goods market like clothing and fashion accessory, etc. The firm would like to gain more market information before making the production or quantity decision. Therefore, under this situation, the firm usually decides the price first and observes the market preliminary response, then the firm determines the operational strategy to satisfy this demand. This is referred as the quantity postponement strategy. Pre-order events for products like video games, fashion goods, or popular books are typical examples of quantity decision postponement.

2. Operational decision is made before the pricing decision. This often happens when the demand is relatively stable but the supply/production takes long lead time, for example, the consumer goods and durable goods in Walmart imported from Asia to North America, or variety of agriculture products which take more than months to grow. Due to the characteristics of the products, the demand variation is usually small but the supply risk may be high due to the long lead time. In this case, the operational planning is more important for the firm to achieve lower cost.

The motivation of sequential decision is the benefit from the information revelation, in particular, demand and yield information revelation in the two cases above. Therefore, coming with the sequential decision making, a natural question to explore is how the decision postponement helps the firm and how the information revelation benefits the firm in each sequential decision case.

The joint price and quantity decision problem, especially the simultaneous decision making problem, have been extensively studied in the literature. Either multiplicative or additive demand form is assumed to reflect the price sensitive demand. This stream of research focuses on finding the optimal price and quantity decisions under different supply chain settings and different operational or marketing restrictions. Most papers show the benefit from flexible pricing option. Petruzzi and Dada (1999) give a general review on this simultaneous decision problem. Under both demand forms, Petruzzi and Dada (1999) study the price and quantity decisions in the single period and multiple period settings and show the optimal strategies. They also discuss the effect of flexible pricing on improving the firm's performance, which is also discussed in our paper. Furthermore, Transchel and Minner (2009) discuss the impact of dynamic pricing under EOQ quantity decision. The property of the timing for price changes is characterized and the benefit from this dynamic pricing is discussed. A recent paper by Chen et al. (2012) study three manufacturer's pricing strategies for operational planning. They suggest that warranties have become a popular measure for encouraging market demand by reducing risks for consumer. Therefore, consumers intend to be risk-averse and treat warranties as compensation paid to consumers in event of product failure. Wang et al. (2009) extend the joint decision model by using the expected utility theory and discuss the influence of flexible price on the optimal quantity decision. Raz and Porteous (2006) analyze the joint price and quantity problem with a fractile approach, by which they show the method to compute the optimal price and quantity under general demand distribution. Deng and Yano (2006) consider the joint price and quantity decision with setup costs and capacity constraints over finite horizons. They characterize the optimal decisions and provide insights on the impact of setup costs and capacity restriction on the optimal policies. Some literature also studies the joint decision problem under multiple products assumption. Wang (2006) studies the case when there are n suppliers selling complementary products and making price and quantity decisions; and Karakul and Chan (2008) discuss the joint pricing and procurement problem with two product types (existing and new products) when the two products have downgrade substitution. The joint price quantity decision problem has also been studied under the context of supply chains. Based on more complex supply chain structure assumption, Wu et al. (2009) study the situation when two supply chains compete and simultaneously determine their price and quantity under demand uncertainty. Li and Atkins (2002) discuss the coordinating strategies between the marketing and operations departments. A simple linear transfer price strategy is studied and the misaligned incentives between the two departments are found to be the main reason for inefficiency. They also provide two ways of reducing this inefficiency. Unlike Li and Atkins (2002), we study the firm with well coordinated pricing and quantity decisions and we focus on the impact of information revelation and decision sequence choices on improving the performance instead of arrangement between departments. Also, we consider the sourcing risk while Li and Atkins (2002) does not. Another related work to ours is Li and Zheng (2006), which discuss the joint replenishment and pricing control with both demand risk and random yield. They analyze the simultaneous decisions under periodic review inventory system and provide the structural results on the optimal policy. Similarly, we show that the system with random yield always charges a higher price, i.e., the immediate cost effect mentioned in Li and Zheng (2006). Besides that, we analyze the benefit from flexible pricing in the simultaneous pricing case. And we further extend the model to study the sequential decision making scenarios and provide insights on the value of demand/yield information.

There is also quite rich literature on the study of random yield. Yano and Lee (1995) provide a comprehensive review on the research topics related to random yield. Henig and Gerchak (1990) provide the structural result for inventory systems with random yield and stochastic demand. Based on Henig and Gerchak (1990), different extensions have been studied. Most research shows that yield randomness hurts the operations and reduces the firm's profit and for inventory systems, usually a threshold stocking policy is optimal. Erdem and Ozekici (2002) analyze a periodic review inventory system with random yield from the vendor's random capacity. Under deterministic demand assumption, Keren (2009) studies the single-period inventory problem with random yield under additive and multiplicative yield models. Also, a recent paper by Li et al. (2008) provides upper and lower bounds for the optimal stocking policy in the periodic review system with random yield and random demand. Recently, more research has focused on the random yield issue in different supply chain settings and the coordination issues in different supply chains with random yield. Gurnani et al. (2000), Gurnani and Gerchak (2007), and Guler and Bilgic (2009) study the coordination in different assembly systems with yield uncertainties of components. Abdel-Malek et al. (2008) model the capacitated newsboy problem and the scenarios studied can be well applied to different distribution systems with random yield settings. He and Zhang (2008) examine different random yield risk sharing contracts in a two-stage decentralized supply chain. Based on this paper, He and Zhang (2010) further analyze the joint effects of random yield and secondary market on supply chains. Wang (2009) discusses the coordination issue in a decentralized supply chain with random yield and random demand by using traditional and VMI arrangement. Kelle et al. (2009) study the buyer–supplier cooperation and negotiation when random yield exists. They study the effects of random yield on supplier and buyer policies and their bargaining process. Mukhopadhyay and Ma (2009) study the joint procurement and production decisions with both random yield and demand uncertainty. They analyze the purchasing and production decisions under three different assumptions on yield and lead time. Dadal and Alghalith (2009) discuss the production/quantity decision under random