



Supply chain coordination with dual procurement sources via real-option contract [☆]



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ABSTRACT

In a two-stage supply chain with a supplier and a manufacturer, the manufacturer can purchase a product either from the supplier or in the spot market. The spot market, however, inevitably involves price fluctuation risk and supply risk. Assuming that the manufacturer is the leader in a procurement game and offers a real-option contract to the supplier, we study the manufacturer's optimal mixed procurement strategy that integrates the use of the real-option contract and the spot market. Moreover, we analyze the effects of the price risk and the supply risk in the spot market on market equilibrium. We show that using the real-option contract mechanism improves the overall expected profit of a supply chain and guarantees supply chain coordination in the presence of the spot market. The results also demonstrate that the price risk and the supply risk in the spot market adversely affect the manufacturer's expected profit. On the contrary, these two risks bring benefits to the supplier.

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1. Introduction

Procurement management has been identified as a major enabler for enhancing core competitiveness of enterprises (Fu, Lee, & Teo, 2010). Traditionally, suppliers and buyers sign bilateral purchase contracts, which are hard to respond to market changes. This is not only because the order quantity and the production quantity are often agreed before the selling season, but also because the lead times are normally very long. In some industries, such as fashion garments, electronics, toy and semiconductor industries, demands change dramatically from day to day because the products have short sales cycles and need quick updates. Generally speaking, manufacturing firms are inevitably confronted with shortages or excess inventories (e.g., key components and raw materials) in the production process because of high market volatility. Large manufacturers, such as General Motors and Boeing, may be held back by their upstream suppliers due to shortages, which in turn limit their profitability (Cachon & Lariviere, 2001).

As demand is becoming more unpredictable nowadays, dealing with replenishment problems becomes crucial in supply chain management.

In order to cope with demand uncertainty, companies begin to adopt flexible purchasing mechanisms, such as buy-back policies (Eppen & Iyer, 1997), backup agreements (Bassok & Srinivasan, 1997), quantity flexibility (Cachon & Lariviere, 2001) and option contracts (Barnes-Schuster, Bassok, & Anupindi, 2002). In the apparel industry, for example, buyers are willing to pay a 30–50% premium to any supplier who can provide a flexible replenishment service (Hunter, King, & Nuttle, 1996). Recently, the option contract has gradually attracted intensive attentions and been adopted in different industries, such as electric power and semiconductor manufacturing (Kleindorfer & Wu, 2003) and consumer electronics (Wang & Liu, 2007). With the option contract, the buyer purchases options from the supplier so that the buyer can be assured a fixed amount of supply in the future. This contract gives the buyer an opportunity to postpone procurement until the actual demand is known (Barnes-Schuster et al., 2002). This paper explores the role of the option contract in offering procurement flexibility and achieving channel coordination in a two-stage supply chain with one manufacturer and one supplier.

The role of e-procurement has become much more critical in the emerging B2B market exchanges. A number of tools, such as

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multi-agent systems, link different buyers and suppliers together (Argoneto & Renna, 2010; Renna & Argoneto, 2010). In this setting, a growing number of companies utilize the existing spot markets for some immediate purchases, in addition to their contractual purchases (Kleindorfer & Wu, 2003). Compared with contracts, the spot market sourcing delivers products at an essentially negligible lead time (Seifert, Thonemann, & Hausman, 2004). Thus, it has been widely used for commodity purchases, such as oil, steel, metals and agricultural products. According to an estimation of the Gartner Group, about 30% of the memory chips used in the semiconductor industry are purchased from the spot markets (Flannery, 1999; Seifert et al., 2004).

Spot market sourcing is flexible but risky (Inderfurth & Kelle, 2011). The first type of risk is price fluctuation risk, as the spot market price is volatile (Kleindorfer & Wu, 2003; Seifert et al., 2004; Wu, Kleindorfer, & Zhang, 2002). For example, the spot market price of memory chips rose over 61% in six weeks in 2009, according to DRAMeXchange. The second type of risk is supply risk. The spot market almost inevitably involves supply uncertainty (Serel, 2007). In November 2011, the heavy flood in Thailand caused serious shortage of hard disks and their spot price became double in two weeks. From the buyer's perspective, spot market sourcing provides an alternative procurement source in order to enhance procurement flexibility. However, it also involves price fluctuation risk and supply risk, which make the purchase decision more complicated and difficult.

In practice, there is a common tradeoff between making a contractual procurement with a supplier and sourcing from the spot market. In order to mitigate risks, HP, for example, has successfully adopted a portfolio approach for purchasing electricity and parts (e.g., memory chips), in which 50% of the spending is through traditional contracts negotiated with suppliers, 35% is on flexible option contract purchases and the remaining 15% is used in the existing spot markets (Billington, 2002; Carbone, 2001). In this paper, we investigate the buyer's optimal mixed procurement strategy that integrates contract and spot market. In the spot market, both price risk and supply risk are involved.

In some industries such as automobiles and aerospace, large downstream manufacturers exert a higher market power than the upstream suppliers and these manufacturers dominate the supply chain (Cachon & Lariviere, 2001). These powerful manufacturers normally have enormous bargaining power to haggle the contract terms with their suppliers. This explains why the option contract is widely used by the manufacturing giants in real-life. Motivated by this, in the two-stage supply chain, we assume that the downstream manufacturer, which offers a real-option contract to the supplier, is the leader. We study the manufacturer's optimal mixed procurement strategy and channel coordination under stochastic demand. The dominant manufacturer has two purchasing sources: the contractual supplier and the existing spot market. Our work aims at addressing the following three research questions:

- (1) If demand is stochastic and the spot market contains both price risk and supply risk, what the manufacturer's optimal procurement strategy would be?
- (2) With the dual procurement sources, how does the manufacturer use the real-option contract to coordinate the supplier's production quantity and to achieve supply chain coordination?
- (3) How do the price risk and supply risk affect the decisions of the supplier and the manufacturer?

The remainder of this paper is organized as follows. Section 2 presents a review of the relevant literature and the model is described in Section 3. In Section 4, we analyze a benchmark case with the price-only contract. In Section 5, we present the market

equilibrium with the real-option contract and explore how the contract can be used to coordinate the supply chain. In Section 6, the impacts of the price risk and supply risk in the spot market on the market equilibrium are studied. Finally, we conclude the paper in Section 7. All proofs are provided in Appendix A.

2. Literature review

This research is related to two streams of literature. The first one is the procurement strategy of supply chain in the presence of spot markets. There is a large body of literature that focuses on procurement issues in the spot markets under deterministic demand. For example, Wu et al. (2002) analyzed the buyer's optimal procurement strategy that integrates contract and spot market in a two-stage supply chain. Peleg, Lee, and Hausman (2002) compared three procurement strategies: the contractual procurement, the online spot buying and the combination of these two. Kleindorfer and Wu (2003) studied the channel coordination issue with a mixed procurement policy, which integrates option contract and spot market sourcing, in the capital-intensive industries. Furthermore, Wu and Kleindorfer (2005) investigated the buyer's procurement policy, provided that the buyer can purchase a product from multiple suppliers or the existing spot market.

There is also a rich literature that discusses procurement management with the integration of contractual agreement and spot market sourcing when both the market demand and spot price are uncertain. Ritchken and Tapiero (1986) studied a mixed procurement strategy that consists of the option contract and the spot market with uncertain demand and an uncertain spot price. Golovachkina and Bradley (2003) analyzed how spot market sourcing affects the coordination in a two-stage supply chain with one supplier and one manufacturer. Seifert et al. (2004) and Akella, Araman, and Kleinknecht (2005) have explored the buyer's optimal procurement strategy and showed that the spot market provides procurement flexibility for the buyer. Haksöz and Seshadri (2007) presented a comprehensive review on the role of spot market sourcing in procurement management. Recently, Talluri and Lee (2010) and Pei, Simchi-Levi, and Tunca (2011) have proposed a methodology for a buyer to select the optimal contract in the presence of the spot market. Fu et al. (2010) examined the buyer's optimal procurement policy and pricing strategy when the buyer can purchase a product either from multi-suppliers who offer different option contracts or from the existing spot market under random and price-dependent demand. Inderfurth and Kelle (2011) compared three procurement strategies: spot market purchase, contractual purchase and the combination of these two. He and Wang (2012) investigated the optimal run time for a production and replenishment policy in the presence of product deteriorations and demand disruptions. Chen, Xue, and Yang (2013) extended to a multi-period model and analyzed the buyer's replenishment policy when confronted with periodic random demand and dual procurement sources. Li, Huang, Cheng, Zheng, and Ji (2014) studied a buyer who can buy service capacity from the spot market or build it in-house. All of the above models have assumed that the spot market has infinite capacity and no supply risk. Only Serel (2007) considered supply uncertainty in the spot market. Our work also considers supply risk in the spot market. While Serel (2007) examined the procurement problems from the buyer's perspective without considering the profitability of the supplier, we study how the real-option contract initiated by the dominant buyer can be used to coordinate the supply chain from both the buyer's and the seller's perspectives.

The other related stream of literature is the supply chain coordination mechanism based on option contract. Option contract was originated from financial economics, in which the value of an option contract is of interest (see e.g., Kawai, 1983; Trigeorgis,

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