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The comparison of two procurement strategies in the presence of supply disruption

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ABSTRACT

The emergency procurement strategy and the optimal allocation procurement strategy are widely used for managing supply disruption risks. In this paper, we investigate two competing manufacturers using these procurement strategies in the presence of supply disruption risks. The joint pricing and ordering decisions of both manufacturers are analyzed using the game theoretic framework. The structural property of the manufacturer with the optimal allocation procurement strategy is characterized by the reliability threshold value, which further determines the equilibrium outcomes for both manufacturers. We find the reliability threshold is a generalization of the supplier's reliability level, which involves all the critical factors that influence manufacturers' procurement decisions under a competitive scenario. The optimal allocation procurement strategy for manufacturer profit maximization in a non-competitive scenario does not necessarily generate competitive advantage in a competitive scenario; under a wide range of parameters, the emergency procurement strategy can produce larger profit for the manufacturer than the optimal allocation procurement strategy when all suppliers are unreliable. The effects of reliability level and costs on procurement decisions are examined using comparative studies and numerical computations.

1. Introduction

Supply disruptions present a real business challenge. Such disruptions may lead to defaults by the suppliers that provide manufacturers with inputs necessary to their production. For example, in April 2010, a volcanic eruption in Iceland shut down production plants all over the world that required key parts from Europe. BBC News reported that Nissan stopped production of three auto models in Japan and BMW cut production in Germany. A 2011 survey found that 85% of manufacturers had suffered multiple supply disruptions (Veysey, 2011).

Supply disruptions can occur for numerous reasons, such as earthquakes, power failures, and terrorist attacks. Increasing price competition, outsourcing and offshoring are driving manufacturers to source from more inexpensive suppliers even when they have imperfect reliability. Therefore, the management of supply risks has become a critical challenge for procurement managers in today's globalized and highly uncertain business environment. Supply risk management has become increasingly important to supply chain management.

To mitigate the negative effects of supply disruption, numerous management strategies have been studied, such as dual-sourcing, emergency sourcing, backup supply, demand management, increasing safety stock, and improving supplier process (Sheffi, 2005; Tang & Kouvelis, 2011; Tomlin, 2006, 2009a, 2009b; Wang, Gilland, & Tomlin, 2010). Although an increasing number of papers have examined supply disruption, most have focused on its effect on manufacturer performance and how to employ operational strategies to mitigate supply risk from the perspective of a single firm. Thus the question remains of what will occur if manufacturers adopt distinct operational strategies to compete under supply disruption risks. Hence, in this paper we study horizontal competition between manufacturers employing distinct procurement strategies. Additionally, when something is in short supply, the price will differ relative to when it is in full supply. For example, on September 21, 1999, a major earthquake in Taiwan caused a tripling of computer memory prices on world markets. Therefore, the effect of supply disruption risks on manufacturer pricing decisions and expected profits should be taken into account when assessing supply disruption risks and market competition.

In this paper, we propose models to study two different procurement strategies adopted by competing manufacturers to mitigate supply disruption risks. We consider a two-echelon supply

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chain that comprises two suppliers and two manufacturers. The manufacturers purchase products from suppliers and transform these intermediate products into differentiated final products, which are then sold in the market. One manufacturer uses an Emergency Procurement (EP) strategy and the other uses an Optimal Allocation Procurement (OAP) strategy. In the base model, one supplier is unreliable but less expensive and the other is perfectly reliable but more expensive. The manufacturer with the EP strategy can purchase products from the spot market and respond effectively to supply disruptions. The manufacturer with the OAP strategy allocates its purchases between both suppliers. The setting in the extension model resembles that in the base model except that the competing manufacturers face two unreliable suppliers. In both models, we examine how the procurement strategies affect manufacturers' ordering decisions and expected profits under supply disruption risks and horizontal competition. This paper obtains some managerial insights. For example, the increasing underage cost implies the increasing possibility of using more reliable supply (reliable sole sourcing; dual sourcing with order inflation; diversification) for the manufacturer with the OAP strategy. Higher procurement cost decreases the possibility of using more reliable supply for the manufacturer with the OAP strategy. The OAP strategy to maximize manufacturer' profit in a noncompetitive scenario does not necessarily yield competitive advantage for a manufacturer in a competitive scenario.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature. Section 3 then introduces and formulates the problem. The base model and extension model are then proposed in Sections 4 and 5, respectively. Section 6 provides numerical computations to develop further insights. Finally, Section 7 summarizes the conclusions and outlines future research topics.

2. Literature review

Supply uncertainty is generally characterized by three approaches. The first approach is the random yield model in which the quantity of units delivered by the supplier is a random fraction of the quantity ordered by the buyer (Babich, Ritchken, & Burnetas, 2007; Dada, Petruzzi, & Schwarz, 2007; Deo & Corbett, 2009; Gurnani & Gerchak, 2007; Yano & Lee, 1995). The second approach models the supply uncertainty as the "all-or-nothing" type called supply disruption. In this scenario, the supplier can deliver either the entire amount ordered or nothing (Li, Wang, & Cheng, 2010; Shou, Huang, & Li, 2009; Tang & Kouvelis, 2011; Tomlin, 2006; Wadecki, Babich, & Wu, 2012). The third approach models the supply uncertainty with a stochastic lead-time or a stochastic capacity (Babich, 2010). In this paper we use the Bernoulli yield (all-or-nothing) to model supplier status.

The related literature comprises two streams. The first stream discusses the procurement strategy for managing supply risks. Sourcing products from multiple suppliers such that a problem at one supplier does not affect the entire supply is called diversification. A diversification strategy can effectively reduce disruption risk but involves higher costs and complexity. Babich et al. (2007) and Dada et al. (2007) provide an in-depth discussion of this strategy. Having an emergency supplier who is not normally used, but can be activated in the event of a supply problem is called a backup strategy or contingent strategy. For example, in response to the air traffic disruption resulting from the September 11th terrorist attack, Chrysler temporarily turned to ground shipping to send components from the U.S. to their Dodge Ram assembly plant in Mexico (Tomlin, 2006). One advantage of a backup strategy is that it incurs costs only in the event of an actual disruption. Hou, Zeng, and Zhao (2010) investigate a buy-back contract between a buyer and backup supplier for use in the event of disruptions affecting the buyer's main supplier. Lu, Huang, and Shen (2011) study a supply chain model in which two substituted products are sourced from two suppliers. Kouvelis and Li (2012) study the potential use of two contingency strategies on top of the conventional time buffer to address lead-time uncertainty. Gurnani, Gümüş, Ray, and Ray (2012) investigate one buyer facing two suppliers under supply risk, and address the buyer's optimal allocation procurement strategy under asymmetric information. Meena and Sarmah (2013) investigate an order allocation problem experienced by a manufacturer with multiple suppliers where there exists risks of supply disruption. They build a mixed integer nonlinear programming model that they solve using the genetic algorithm. Unlike the existing literature, which investigates a single buyer that employs a diversification strategy or backup strategy to manage supply disruption risks, our paper focuses on strategic interactions among buyers/manufacturers that occupy a competitive setting and commit to different procurement strategies.

The second stream of related literature details manufacturer/retailer competition under supply disruption risk. Shou et al. (2009) discussed competition between two supply chains, subject to supply uncertainty. Deo and Corbett (2009) build a two-stage model of a Cournot competition among several suppliers to investigate the effect of supply uncertainty on buyer entry and production strategies. Tang and Kouvelis (2011) investigate a dual-sourcing strategy by studying the benefits of supplier diversification for dual-procurement duopolists. Chen and Guo (2014) develop an analytical model to evaluate competing retailers' sourcing strategies under supply uncertainty. They consider a common supplier that sells its uncertain supply. Our paper differs from the previous literature in several ways. First, we use a different setting to study manufacturers' competitive behavior. Second, we consider the OAP and EP strategies for managing supply disruption risks, which were not investigated in the existing literature, using the game theoretic framework. Third, we jointly consider pricing and ordering decisions.

3. Model description and assumptions

We consider a two-echelon supply chain comprising two suppliers and two manufacturers. Both manufacturers replenish their stocks from upstream suppliers and compete in a market vulnerable to supply disruption risks. The two manufacturers provide differentiated products. The supply chain model is depicted in Fig. 1. The product has a short life cycle and is sold in a single selling season. One of the suppliers is perfectly reliable but expensive, while the other is unreliable but less expensive. This setting is generally used in the literature (Babich et al., 2007; Chen & Guo, 2014; Gurnani et al., 2012; Hou et al., 2010; Li et al., 2010; Serel, 2008; Tomlin, 2006). We assume that supplier 1 is perfectly reliable and there is some probability that supplier 2 may experience disruption. If supplier 2 is disrupted, it becomes unable to provide essential inputs for downstream manufacturers. The two manufacturers use distinctive procurement strategies to mitigate supply

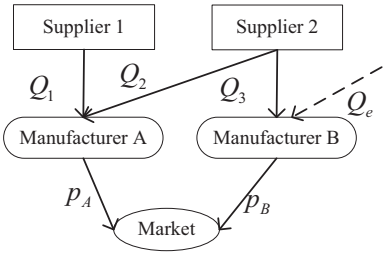

Fig. 1. Supply chain model.