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Procurement mechanism for dual sourcing and emergency production under capacity constraint

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ABSTRACT

This study investigates the optimal procurement mechanism of a buyer who faces two potential suppliers with capacity constraint and private information on costs. The buyer places regular orders to the capacitated suppliers before demand realization and has the option to place an expensive emergency order depending on remaining capacity after that. We observe that the buyer solely exercises emergency option when the virtual cost of the first supplier (with low cost) is greater than emergency production cost. When this virtual cost is not too large, the buyer chooses dual sourcing solely, dual sourcing with emergency option, and single sourcing with emergency option when the capacity is small, moderate, and large, respectively. Compared with symmetric information, information asymmetry weakens capacity constraint for the buyer in terms of order quantity in regular sourcing. However, in terms of order quantity in emergency sourcing, information asymmetry either strengthens capacity constraint when total capacity is greater than expected demand, or weakens capacity constraint when the opposite is the case. Furthermore, the capacity constraint of the first supplier causes a greater buyer's profit loss than the second supplier (with high cost) does under symmetric information, and information asymmetry further amplifies this asymmetric effect. We also show that the dual sourcing mechanism can be extended to the case of multiple sourcing without loss of the main properties.

1. Introduction

Most firms, particularly in high-tech industry, are subject to capacity constraint. When a buyer (manufacturer) faces capacitated upstream firms and large potential customer demand, dual sourcing becomes a popular choice. For instance, Apple usually purchases retina panels from Sharp and LG Display (AppleInsider, 2013) and Boeing procures aircraft seats from Zodiac and B/E Aerospace (Gates, 2014). However, in the real world, dual sourcing still frequently encounters difficulty in coping with demand uncertainty. As a result, buyers need to exercise emergency order at a higher cost after demand realization (Fu, Hsu, & Lee, 2009). Similar to dual sourcing, the emergency option is also subject to upstream capacity constraint. For instance, after Sharp and LG failed to reach the required production volumes, Apple turned to purchase some of the high-resolution retina panels from Samsung (AppleInsider, 2013). However, even after engaging in dual sourcing and emergency option, Apple still failed to obtain sufficient panels and could not extensively launch the new iPad Mini because only a few firms have the capability to develop such high-tech components (Reuters, 2013; Tyrsina, 2013). Even worse, when all suppliers in an industry are under serious shortage, downstream firms cannot acquire any component through the emergency option. In 2014, Zodiac and B/E Aerospace were unable to cope with the vast workload of lie-flat seats because of record demand. Thus, Boeing had to delay the delivery of two 787 Dreamliners because no other company could provide emergency supply (Gates, 2014).

Based on the practical examples, it is critical for a buyer to plan its dual sourcing (regular sourcing) and emergency production under upstream capacity constraint and uncertain customer demand. In particular, the buyer firstly needs to determine how much of suppliers' limited capacity is allocated for regular sourcing and how much for emergency option. Regular sourcing is exercised before demand realization, thus it is cheap but facing uncertain demand. Emergency option is activated after demand realization, thus it is expensive but facing certain demand. Further, in regular sourcing, the buyer needs to determine to source from single or dual suppliers. Sourcing from single supplier means small possibility of over production but large possibility of lost sale. Sourcing from dual suppliers means small possibility of lost sale but large possibility of over production. Balancing the trade-offs between regular sourcing and emergency production, and between single sourcing and dual sourcing is an interesting research question.

In addition to capacity constraint, information asymmetry is

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another issue in the application of dual sourcing and emergency option. According to IndustryWeek (2009), more than 40% of downstream firms lack transparency of their tier 1 suppliers. For tier 2 suppliers, this figure increases to 75%. In practice, production cost is the most common private information (Chaturvedi & Martínez-De-Albéniz, 2011; Duenyas, Hu, & Beil, 2013), and generally, the buyer needs to design a mechanism to solve this problem. Then, how the presence of information asymmetry affects the allocation of capacity for regular sourcing and emergency option is another intriguing question.

Several studies have examined the combination strategy of dual/multiple sourcing and emergency option (e.g., Klosterhalfen, Kiesmüller, & Minner, 2011; Merzifonluoglu, 2015; Veeraraghavan & Scheller-Wolf, 2008). However, these studies investigate procurement issues under symmetric information and exogenously set the regular and the emergency suppliers. To explore the strategic usage of dual sourcing and emergency production under capacity constraint and asymmetric information, we propose the following model. A buyer sources an essential component for its product from two capacitated suppliers to meet uncertain demand. Each supplier has a low regular production cost which is his private information, and a high emergency production cost which is common knowledge. The buyer places regular orders to the suppliers before demand realization and places an emergency order if necessary depending on the remaining capacity after demand realization.

This model sheds light on the following research questions. First, under symmetric information, should the buyer select a single supplier or dual suppliers in regular sourcing, and reserve capacity for emergency option? Our research shows that when capacity is small, dual sourcing solely is active. When capacity is moderate, dual sourcing and emergency option are active. When capacity is large, the buyer prefers single sourcing with emergency option. Second, how does information asymmetry affect the buyer's decisions and particularly what is the impact of information asymmetry on the capacity constraint for the buyer in terms of order quantity decisions? Interestingly, we find that a unique strategy emerges in the case of asymmetric information compared with symmetric information, i.e., emergency sourcing solely. This strategy is active when the virtual cost of the first supplier (with low regular production cost) is greater than the emergency production cost. Further, compared with symmetric information, information asymmetry weakens the capacity constraint for the buyer in terms of regular order quantity allocation. In terms of the emergency order quantity decision, information asymmetry strengthens (weakens) the capacity constraint for the buyer when the total capacity is greater (less) than the expected demand. Third, what is the impact of capacity constraint on buyer's profit, and how does information asymmetry influence it? Our analysis shows that the capacity constraint of the first supplier generates a greater buyer's profit loss than that of the second supplier (with high regular production cost) does, and information asymmetry amplifies the difference between the profit losses.

The rest of this paper is organized as follows. Section 2 reviews the related literature. Section 3 presents the model setup. Sections 4 and 5 characterize the sourcing strategies under symmetric and asymmetric information, respectively. Section 6 provides numerical studies. We extend our model in Section 7, and conclude this paper in Section 8. All the proofs are included in the Appendix.

2. Literature review

In the research of supply chain management, there are three streams of literature most related to this paper. The first stream focuses on the issue of dual/multiple sourcing under capacity constraint. Rosenblatt, Herer, and Hefter (1998) develop the optimal order policy in EOQ model when a firm faces multiple capacitated suppliers. Taking suppliers' capacity constraints and total cost of logistics into account, a mixed integer non-linear programming model is proposed by Ghodsypour and O'Brien (2001) to select suppliers and determine the order quantities from suppliers. Qi (2007) adopts an integrated decision making model to find the optimal selling price for a buyer who faces multiple capacitated suppliers and price sensitive demand. Yazlali and Erhun (2009) examine a periodically reviewed dual-supply inventory problem in which a manufacturer is supplied by two suppliers with limited capacities and consecutive lead-times. Iakovou, Vlachos, and Xanthopoulos (2010) investigate a stochastic inventory decision-making model when two suppliers have supply risks and capacity constraints. Zhang and Hua (2013) investigate a periodic review inventory problem, considering a buyer sources from two suppliers and faces the fixed cost and order size constraint with the lower cost supplier. Tan, Feng, and Chen (2016) analyze a multi-period procurement problem when the buyer can replenish inventory from two suppliers with random capacities. Under the framework of triple sourcing, Mohammadzadeh and Zegordi (2016) study the optimal ordering policy of the manufacturer when the two reliable suppliers decide production capacities and the main supplier has disruption risk. Different from above works, our paper studies the buyer's strategic combination of dual sourcing and emergency option when the suppliers have limited capacity.

The second stream of literature concentrates on the emergency (backup) sourcing problem under supply risk or demand uncertainty. Tagaras and Vlachos (2001) consider a periodic review inventory problem with two replenishment options: the first option is the regular order which has a lower cost and a longer lead-time; the second option is the emergency order which has a shorter lead-time and a higher cost. Kouvelis and Milner (2002) investigate the model in which a firm faces both random demand and random supply during two stages. To meet the need for non-core activities in the second stage, the firm can either produce products internally or depend on outside backup supplier. Babich (2006) proposes a multi-stage model of a two-level supply chain with one manufacturer and two risky suppliers. The suppliers are different in production lead-times, and the manufacturer has backup option to order from the faster supplier after the risk has been partially resolved. Fu et al. (2009) analyze the procurement problem of a manufacturer who sources a number of components for the final product and faces uncertain demand. The components can be either ordered at normal prices before demand realization, or ordered at higher prices after that. Xing, Wang, and Liu (2012) study the sourcing strategy of a retailer who can obtain extra products through a B2B spot market after regular sourcing and demand realization. Axsäter (2014) analyzes a single-echelon continuous review inventory system with Poisson demand and emergency orders. In the presence of demand uncertainty, Sali and Giard (2015) focus on the emergency sourcing problem in the assemble-to-order framework. He, Huang, and Yuan (2015) consider the sourcing problem when competing buyers can adopt different sourcing strategies, emergency procurement strategy or optimal allocation procurement strategy, to mitigate supply disruption risk. Hou, Zeng, and Sun (2017) examine the capacity reservation contract between a buyer and a backup supplier when the primary supplier has disruption risk. Different from above works which exogenously set the regular and the emergency suppliers, in our study, the buyer endogenously determines the regular supplier(s) and the emergency supplier, since each potential supplier with limited capacity can exercise either regular production or expedited production.

There are several studies that involve both dual/multiple sourcing and emergency option. Klosterhalfen et al. (2011) analyze a periodic-review inventory system with random demand and two suppliers, a regular supplier and an expedited supplier, where unsatisfied demand is backordered. Huang and Xu (2015) propose a model in which a firm orders from two unreliable major suppliers and decides whether to reserve backup option from a reliable supplier. Merzifonluoglu (2015) investigates the sourcing strategy for a firm who has multiple unreliable primary suppliers with limited capacities and a reliable backup supplier with unlimited capacity. The aforementioned papers do not examine the impact of capacity constraint on either regular supplier(s) or

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